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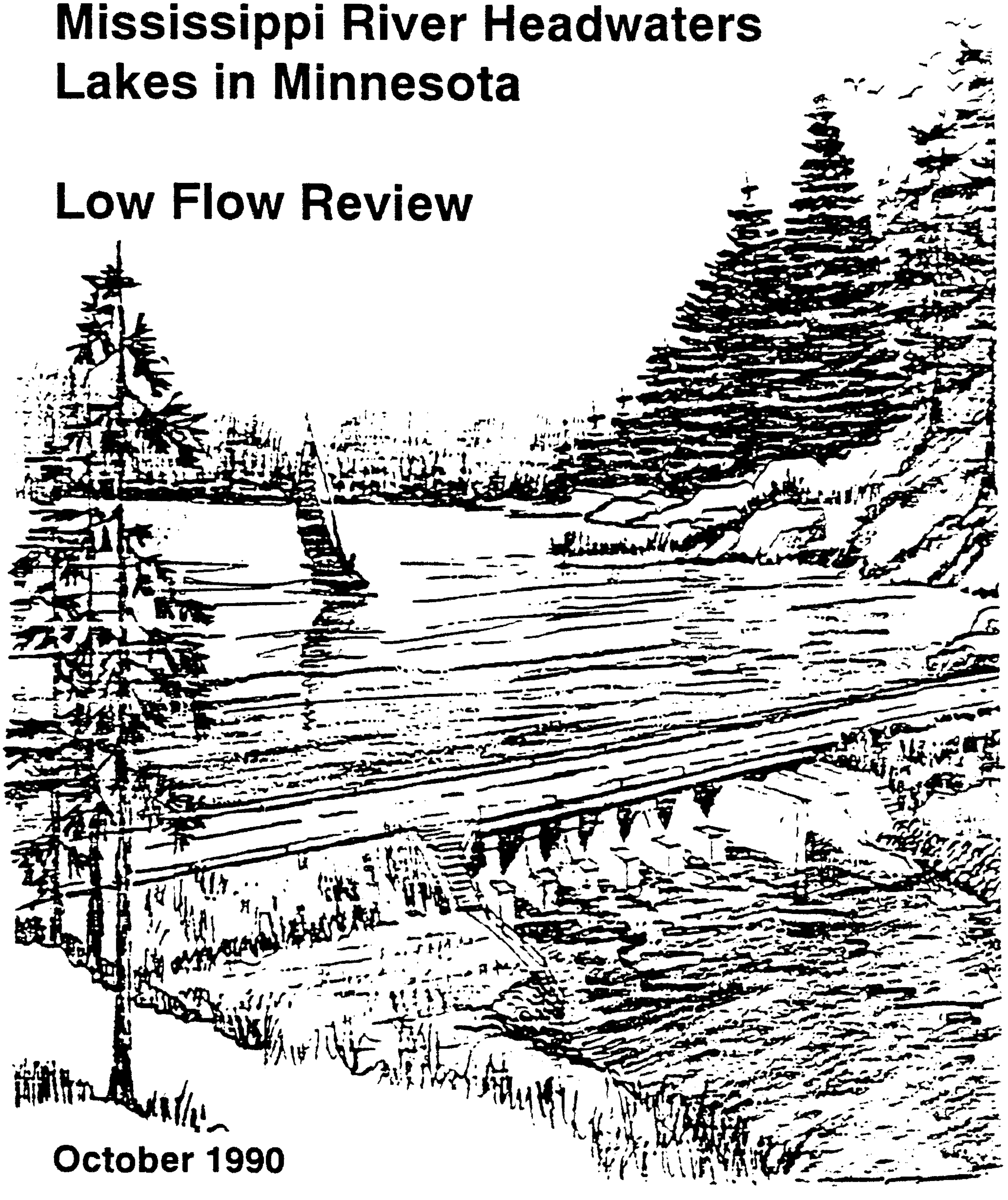
US Army Corps
of Engineers
St. Paul District

Final

Mississippi River Headwaters Lakes in Minnesota

Low Flow Review



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In response to the 1988 drought, the St. Paul Distict, Corps of Engineers reviewed the low flow portion of its water control plan for the Mississippi Headwaters lakes projects. This review concludes that the routine flow discharge rates for each project lake are adequate for present needs. However, some institutional aspects need updating. This report contains proposed changes to the low flow plan including 1. interagency coordination procedure with specific triggers for stepped responses as conditions worsen, including identification of low flow emergency conditions in the Minnespolis-St. Paul metropolitan area; 2. organization of the St. Paul district in-house drought management team and 3. preparation and use of a public information plan specific to droughts.
The relative priority for use of Federal project waters at the Headwaters project is commericial navigation first, Treat Trust resources second, and general public good third. It is expected that emergency cond'tions that would justify releases in excess of the routine low flow plan to be rare. This report describes the decision-making and

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19. Abstract continued:

coordination process that would be followed by the St. Paul District, Corps fo Engineers in the unlikely event that emergency supplemental flows might be needed from the Headwaters lakes project.

EXECUTIVE SUMMARY

In response to the drought in 1988, the St. Paul District, U.S. Army Corps of Engineers reviewed the low flow portion of its water control plan for the Mississippi Headwaters Lakes projects. This review concludes that the routine low flow discharge rates for each project lake are adequate for present needs. However, some institutional aspects of the low flow plan need updating. This report contains proposed changes to the low flow plan, including: (1) interagency coordination procedure with specific triggers for stepped responses as conditions worsen, including identification of low flow emergency conditions in the Minneapolis-St. Paul metropolitan area; (2) organization of the St. Paul District in-house drought management team; and (3) preparation and use of a public information plan specific to droughts. Additional conclusions and recommendations are found, beginning on page 56 of this report.

Typically, waters from the project's lakes are discharged in accordance with the routine low flow plan for commercial navigation and other downstream purposes. The routine low flows also provide a significant benefit to the first 50 to 75 miles of aquatic habitat and other instream needs below each project dam. Under emergency conditions, particularly for human health and safety, the routine low flow discharges from the project lakes can be supplemented.

The relative priority for use of Federal project waters at the Headwaters project is commercial navigation first, Treaty Trust resources second, and general public good third. The Minnesota Department of Natural Resources (MDNR) and the Minnesota Chippewa Tribe do not support this relative priority. However, both agree that human health and safety emergencies, such as a shortage of potable water, could temporarily supersede these 3 priorities. The Federal Government's Treaty Trust responsibility stems, in part, from a treaty that was entered into by Congress in 1855, with later modifications, that reserved areas for the Ojibwa people to live and use resources in the Headwaters Lakes area. The project authority for commercial navigation was created by Congress in the Rivers and Harbors Acts of 1880 and 1882, with later modifications. In 1944, Congress recognized that the commercial navigation purpose had diminished with construction of the locks and dams system on the Upper Mississippi River. Thus, Congress added the somewhat vague purpose of "general public good" to the authorized project purposes, but at a lower priority than commercial navigation. The relative priority of the commercial navigation authority over Treaty Trust responsibility comes from interpretation of previous Federal court decisions.

It is expected that emergency conditions that would justify releases in excess of the routine low flow plan would be quite rare. The current Mississippi River emergency-level discharge of 554 cfs for 7 days, can be expected to occur, statistically, about once every 100 years. Emergency flow (554 cfs) events of longer than 7 days would be expected to occur less frequently. The St. Paul District will not recognize an upward revision of the emergency discharge of 554 cfs without first consulting with the Minnesota Chippewa Tribe. Further, ongoing planning efforts by the State of Minnesota, the Metropolitan Council, and individual municipal water

utilities are expected to reduce the risk of occurrence and the overall magnitude of the impact of a given emergency low flow condition. The MDNR and Metropolitan Council together have prepared a Drought Response Plan shown on Table 6 of the Council's Short-Term Water Supply Plan, dated February 1, 1990. The Council/MDNR Drought Response Plan is shown on the next 2 pages. The Council/MDNR matrix is consistent with the Agency Drought Coordination Matrix that is described in the section immediately following this Executive Summary. The Council/MDNR matrix is specific to the actions that would be taken in the Twin Cities area by these agencies. The Agency Drought Coordination Matrix summarizes the coordination and actions to be completed by the various levels of government at each stage of a worsening drought.

This report describes the decision-making and coordination process that would be followed by the St. Paul District, Corps of Engineers in the unlikely event that emergency supplemental flows might be needed from the Headwaters Lakes project. Droughts involve so many variables that it is impossible to "pre-plan" alternative water control actions in detail for all potential drought scenarios. Thus, the process for decision-making has been defined, rather than attempting to formulate all possible alternative scenarios. The decision-making process is illustrated using 3 scenarios, and it must be understood that the 3 scenarios are <u>not</u> preconceived for all future water control decisions.

The decision-making process conceptually follows the Federal water resources planning system established in the Principles and Guidelines: (1) verify the emergency need for surplus low flows; (2) formulate alternative emergency discharge plans based on professional consideration of prevailing physical conditions; (3) evaluate effects of each alternative, including effects on Treaty Trust resources; and (4) implement, monitor and adjust the best plan as needed.

The Public Information Plan is extremely important, particularly for the outstate stakeholders. The Headwaters Board is a valuable asset for providing a public forum for exchange of project related information. The individual Chippewa Bands may also wish to hold meetings with the assistance of the District Tribal Coordinator and Drought Team representatives. Also, the District should identify an official spokesperson and notify media contacts that a spokesperson is available for answering questions and attending press conferences. The spokesperson is also responsible, with the assistance of the Public Affairs Officer, to ensure that regular and special news releases are made. The news releases should contain specific factual information to help minimize misconceptions about the low flow event.

At this time, the Emergency Phase trigger of 554 cfs for 72 hours at Anoka will be verified, through agency coordination, based on then current emergency water needs for navigation and human health and safety purposes. The review would be needed to determine whether the emergency needs have changed from the 1990 figure of 554 cfs (350 cfs commercial navigation, 202 cfs municipal supply plus 2 cfs NSP), measured at the Anoka gage. However, consultation will occur with the Minnesota Chippewa Tribe before the Emergency Phase trigger would be revised upward.

Restriction Phase - This phase is defined as when the 72-hour flow at Anoka is at or below 750 cfs. The routine low flow plan will be followed during the Restriction Phase.

The District Drought Team Coordinator will direct the team to formulate and evaluate alternative plans for releasing emergency low flows from project lakes when the Restriction Phase is expected to occur in the next 30 days, based on the NWS flow predictions. Examples of the planning process to formulate alternative emergency release plans are contained in this report, primarily as a guideline to future District Drought Team members that may not have been involved with this 1990 review study. The planning process will be accomplished in consultation with the Bureau of Indian Affairs and Chippewa Tribal governments, MDNR personnel and others, as needed.

Some of the factors used to compare the effects of alternative emergency release plans will include: effects on Treaty Trust resources, recoverability of individual reservoirs, prevailing lake levels and stream flows, recreation economics and environmental effects. Effects of emergency releases on both downstream and in-lake resources will be considered in evaluating and comparing the alternatives being considered to make the emergency release. The information will be used by the District in formulating the best way to release supplemental low flows, if any are needed, from Headwaters Lakes. Information about the plan formulation and decision-making process and findings will be made available to the public.

During the Restriction Phase, it would seem most prudent to use Mississippi River flows, as much as possible, to maintain maximum offstream storage in the City of St. Paul water system to be prepared in the event that the Emergency Phase occurs. This would help minimize the total volume of emergency releases from the Headwaters project.

SUMMARY OF DISTRICT'S EMERGENCY LOW FLOW DECISION PROCESS

During low flows on the Upper Mississippi River, the District coordinates with others in accordance with the Agency Drought Coordination Matrix, shown on the next page. The following paragraphs indicate what the District expects to do and when during each phase of the drought.

Normal Conditions - The routine low flow plan will be followed. Normal agency coordination will occur, as summarized in the Agency Drought Coordination Matrix and in detail in Appendix D.

Drought Watch Phase - The routine low flow plan will be followed during a Drought Watch Phase. The Drought Watch Phase is not triggered by a specific river discharge. Rather, it is triggered by a combination of factors, including: precipitation deficiencies, declining streamflows, Palmer Drought Index, frost depths, lake and reservoir levels and groundwater conditions. The State Climatologist, other Minnesota Department of Natural Resources (MDNR) employees, and the National Weather Service (NWS) routinely monitor these factors and can indicate when a Drought Watch is underway.

Typically, the Minnesota DNR would convene the initial meeting of the Governor's Drought Task Force, based on the status of the drought indicators. The runoff meetings that are routinely attended by the District Water Control Center, beginning in each February, would also be an opportune time to determine the need for convening the Drought Task Force. However, any member of the Task Force may also request that the group convene at any time. The District Drought Coordinator should also notify the Bureau of Indian Affairs (BIA) and Chippewa Tribal representatives of any Drought Task Force meetings that the District is involved with. The objectives of the Task Force meetings are to exchange information, determine the need to obtain further information, and discuss the likelihood of occurrence of public health and safety emergencies resulting from the drought.

Conservation Phase - This phase is defined as when the 72-hour flow at Anoka is at or below 1,000 cfs. The routine low flow plan will be followed during the Conservation Phase.

In-house drought team members will be assigned and begin meeting when the National Weather Service (NWS) 30-day prediction indicates that the Conservation Phase will occur. At the meetings, the Drought Team Coordinator will ensure that the team is thoroughly familiar with the low flow emergency decision-making procedure contained in this report. The Drought Team members will ensure that the information bases required for this decision-making process will be current, when needed. Further, Drought Team members will consider the need to coordinate with other agencies and monitor and document low flow conditions, including, but not limited to: water quality, instream flow evaluations, Treaty Trust resources and remote sensing. Monitoring and documentation may begin as required and if funds are available. The District would provide information concerning project status to the public and continue to participate in the State Drought Task Force.

Emergency Phase - This phase is identified as when the flow at Anoka is at or below the emergency discharge figure, determined to be 554 cfs in 1990.

The District will determine the timing and amount of emergency flows from the Headwaters project lakes, if needed, to support the emergency flow requirements of 554 cfs at the Anoka gage. The District's emergency actions will be triggered by the NWS 30-day prediction of the emergency discharge. The 30 days of lead time is expected to provide 5 to 10 days to determine and properly coordinate the emergency decision, in addition to travel time for project waters to reach the Anoka gage.

It is noted that the emergency phase does not automatically trigger a specific, predetermined amount of emergency discharge from the Headwaters project lakes. The District will compute the required emergency discharge, based on the prevailing emergency conditions. The District will consult with Minnesota Chippewa Tribal government representatives, MDNR and BIA in determining the amount and timing of emergency releases. Coordination will also occur concerning sources of low flows from non-project Headwaters area lakes, such as from Cass Lake, Lake Bemidji and others.

Emergency releases from the Headwaters project lakes are contingent upon the imposition of appropriate water use restrictions, as summarized by the MDNR in their Drought Response Plan. The District Drought Team will coordinate with the MDNR to determine what allocations have been suspended by the MDNR, prior to making emergency low flow releases.

Emergency releases from the Headwaters project lakes are also contingent upon coordination with the main stem dam operators from Grand Rapids to the Coon Rapids Dam to solicit their cooperation in water control to prevent induced discharge shortages during flows at Anoka less than 1,000 cfs. This coordination is probably best accomplished as a cooperative effort between MDNR and District Drought Team representatives.

Adjustments and Termination of Emergency Releases - Emergency releases from the Headwaters Lakes project may need to be adjusted periodically, based on changes in the NWS 30-day outlook. However, if discharge adjustments are required during extreme low flows, they should only be changed slowly and infrequently, perhaps every 2 to 3 weeks. It would be ineffective to adjust project discharges daily, in response to daily discharge fluctuations at the Anoka gage, because of the extended travel time between the lakes and the gage. If emergency releases are found to be ineffective or no longer needed, they will be terminated immediately.

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT)

TABLE OF CONTENTS (CONT)

TABLES

MAPS

APPENDICES

OBJECTIVES OF LOW FLOW REVIEW

The drought conditions of 1988 reduced flow in the Mississippi River to near critical levels. Minnesota Governor Rudy Perpich asked the St. Paul District, Corps of Engineers, for supplemental releases from the Mississippi River headwaters reservoirs. The additional releases would have supplemented the established minimum flow releases to meet downstream water usage requirements. The supplemental releases were ultimately not made because of rainfall in August in the Upper Mississippi River Basin; however, the drought pointed out the need for improvements in the drought response process and for expanded monitoring of water use, streamflow, and water quality. The objectives of this low flow review has been to evaluate the adequacy of the routine low flow plan, establish in-house and interagency response procedures, and improve the information base that is needed by the St. Paul District to make informed decisions for low flow operation of the Mississippi River Headwaters Lakes project. Additional information would be useful for low flow that affect tribal resources. This review also identifies emergency conditions under which emergency releases, in excess of the routine low flow plan, might be considered.

AUTHORITY FOR THIS LOW FLOW REVIEW

This review of the low flow portion of the water control plan for the Headwaters Lakes Project is being conducted as part of the St. Paul District Engineer's routine water control responsibility for the project. No special Congressional or higher command authority is needed to accomplish this review. Funding for this work has come from the operations and maintenance funds for the project.

PROJECT AUTHORIZATION

Construction of the dams at each of the six Mississippi River headwaters lakes was authorized by the River and Harbor Acts of June 14, 1880 and August 2, 1882. In 1888, Congress directed the Secretary of War to establish regulations governing their operation. General regulation were first established by the War Department in 1889 and later formally modified in 1931, 1935, 1936 and 1944. The wording of the original regulations and

rationale for the changes can be found in the 1982 Feasibility Report, Mississippi River Headwaters Lakes in Minnesota, Appendix B, pages B-1 to B-20.

The existing project, authorized by the 1899 River and Harbor Act with later modifications, provided for reconstruction of dams from timber design to concrete design at Winnibigoshish, Leech, Pokegama, Sandy, and Pine River Dams, and construction of a concrete dam at Gull Lake. The Corps of Engineers completed the headwaters reservoirs project, in its present form, in 1913.

AUTHORIZED PROJECT PURPOSES

The primary purpose of the six headwaters dams constructed between 1881 and 1912 is to provide flow augmentation for Mississippi River navigation at and below St. Paul, Minnesota. The area surrounding the headwaters lakes was occupied by the Minnesota Chippewa people when the dams were first built, and the Chippewa leaders were concerned about the effects of widely fluctuating lake levels on the wild rice and other resources. Later, other interests grew concerned with lake regulation as lakeshore development for recreation and resort purposes and downstream agricultural development occurred. These concerns have translated to a desire for stable lake levels for the six project lakes by the project area residents.

The need for water releases from the six lakes for navigation was greatly reduced after completion of the Mississippi River 9-foot channel project, during the 1930's. However, for commercial navigation, the Headwaters project is most needed under low flow conditions. The existing locks and dams in the Twin Cities area require a flow of 350 cubic feet per second (cfs) for lockages at St. Anthony Falls, the most sensitive of the locks to flow. Thus, the commercial navigation purpose remains for the Headwaters Lakes project, particularly during low flow conditions on the Mississippi River.

The Secretary of War issued new regulations during the period 1931-1945 for regulating the six headwaters lakes, as a result of local interest demands, reduced flow augmentation needs for navigation, and related downstream

water needs. The 1936 War Department Regulations and the 1944 modifications to them are still in effect for the Mississippi River headwaters lakes.

Although the project was originally authorized only for navigation, the reservoirs are now also regulated to reduce flood stages in the vicinity of Aitkin, Minnesota, and to facilitate use of the project area for recreational purposes and fish and wildlife conservation when it doesn't interfere with the primary navigation purpose. Relatively stable lake levels contribute to recreational use on the lakes, fish and wildlife production, reduction of shoreline erosion and related protection of archaeologic sites on shorelines, and wild rice production. The regulated outflow from the reservoirs, including the low flow plan reviewed in this report, contributes to improved water supply, water quality, stream habitat quality, power generation, and industrial water use.

The House Committee on Rivers and Harbors passed a resolution on June 7, 1945, requesting review of the headwaters lakes water control operation Several interim studies have been completed in response to that resolution; the most recent, prior to this low flow review, was completed in 1982. That study attempted to identify and resolve reservoir related problems. The report recommended that the reservoirs continue to be regulated essentially as they had been for all the authorized and recognized purposes and incorporate operation charges for conservation purposes for Winnibigoshish and Leech Lakes. The report concluded that the existing regulation plan allows the St. Paul District Engineer flexibility in responding to the needs of all interests affected by regulation of the project. The review of the headwaters low flow plan has also been completed in partial response to that resolution.

WATER CONTROL AUTHORITY FOR THE HEADWATERS PROJECT

The St. Paul District Engineer has complete and independent responsibility and authority for water control of all six headwaters dams, within specific constraints established by Congress and higher U.S. Army and Corps of Engineers Command. This responsibility has been delegated from Congress,

through the Secretary of the Army and the Chief of Engineers, to the St. Paul District Engineer.

During the 1988 low flow event, the State of Minnesota raised the issue that it shared water control authority for the six dams because of a 1961 Minnesota statute. See Appendix M. As a result of the 1961 statute, the Commissioner of Conservation (now known as the Department of Natural Resources) issued an order on April 19, 1963, that outlined a comprehensive operational plan for the headwaters reservoirs. A copy of the Commissioner's order is found on pages B-21 to B-43 of the 1982 Mississippi River Headwaters Lakes in Minnesota Feasibility Study.

In actual practice, the St. Paul District attempts to coordinate lake operation in conformance with the 1963 Commissioner's order, whenever possible. However, the St. Paul District Engineer is also charged with the responsibility to consider the project's effects on other project area interests that are not necessarily represented by the Minnesota Department of Natural Resources (MDNR) Commissioner. Thus, in response to the Congressional authority for the project, the District Engineer may vary from the 1963 Commissioner's order at any time.

States have wide powers to legislate the use of property within their borders, except that these powers are restricted by several paramount Federal powers granted under the Constitution. Civil Works water resource projects, such as the headwaters dams, are built under Congressional authorization and are not subject to concurrent authorization by State agencies, unless specifically provided for by Congress.

In fulfilling his duties, the St. Paul District Engineer will consult with the State of Minnesota and the Minnesota Chippewa Nation, and other interested parties, concerning the water control operation of the six headwaters dams.

The State versus Federal water rights issue is not unique to the headwaters reservoirs project. It had been and is being raised nationwide by many States. Thus, the issue often is likely to appear for other projects and in other States. The issue is confusing to the general public, the media,

and project area residents. Thus, the Drought Management Team must be prepared to continually provide accurate information concerning the issue, in accordance with a public information plan.

Public confusion has occurred concerning the state's role in water control for the project dams, probably as a result of a combination of things that have occurred over time, including the 1961 state statute, the 1982 Corps of Engineers Headwaters Feasibility Report (particularly Appendix D), federal regulations and events at past public meetings. See Appendix M. These combined factors have probably contributed to the public misperception that there were no public officials "in charge" during the 1988 low flows. The District Drought Team Coordinator, or a selected team member, should be made available for all public meetings and hearings concerning the project. This includes any public meetings held by the MDNR or Mississippi Headwaters Board concerning the project. A clear explanation should be given concerning the District's water control decision-making process and the role of Chippewa Treaty Trust in that process. State officials should provide a description of state interests and any applicable MDNR regulations. It would probably be most helpful for general public understanding of the project, to emphasize the cooperative nature of the multi-agency effort that is underway for the sake of the resources, rather than emphasize inter-agency differences of opinion over water rights. If pressed, any interagency issues should be explained objectively, followed by a re-emphasis of the need for cooperative effort, particularly during emergencies.

AGREEMENTS CONCERNING HEADWATERS PROJECT PURPOSES AND REGULATIONS

The St. Paul District has no formal agreements with other agencies regarding the regulation of any of the headwaters lakes.

There is an informal agreement between the St. Paul District and the Minnesota Department of Natural Resources that, in matters concerning regulation of the headwaters lakes that affect State interests, issues will be decided after consultation with tribal governments, the Minnesota Department of Natural Resources and other affected parties.

Treaty rights, court rulings, and Federal regulations provide for protection of Amercian Indians water rights, and impose a trust responsibility on the Federal Government. The key point to be emphasized is that the interests of the Americans Indians must be taken into consideration, with their input to the District Engineer's decision-making process. American Indian Bands with interest in the headwaters area resources are:

Band	Reservoir
Leech Lake Band Chippewa	Leech, Winnibigoshish
Mille Lacs Band Chippewa	Sandy

Collectively, then Chippewa Bands are represented by the Minnesota Chippewa Tribe.

As a result of a study conducted by the St. Paul District on the headwaters project and completed in 1982, an informal agreement was made between the Leech Lake Chippewa Band the St. Paul District concerning stable pool levels during wild rice growing seasons in Leech Lake.

There is an informal agreement with the MDNR regarding delay of drawdown of Pine River reservoir each fall until approximately mid-December to enhance whitefish spawning in the reservoir. Another informal agreement exists with the MDNR for water control for walleye stripping.

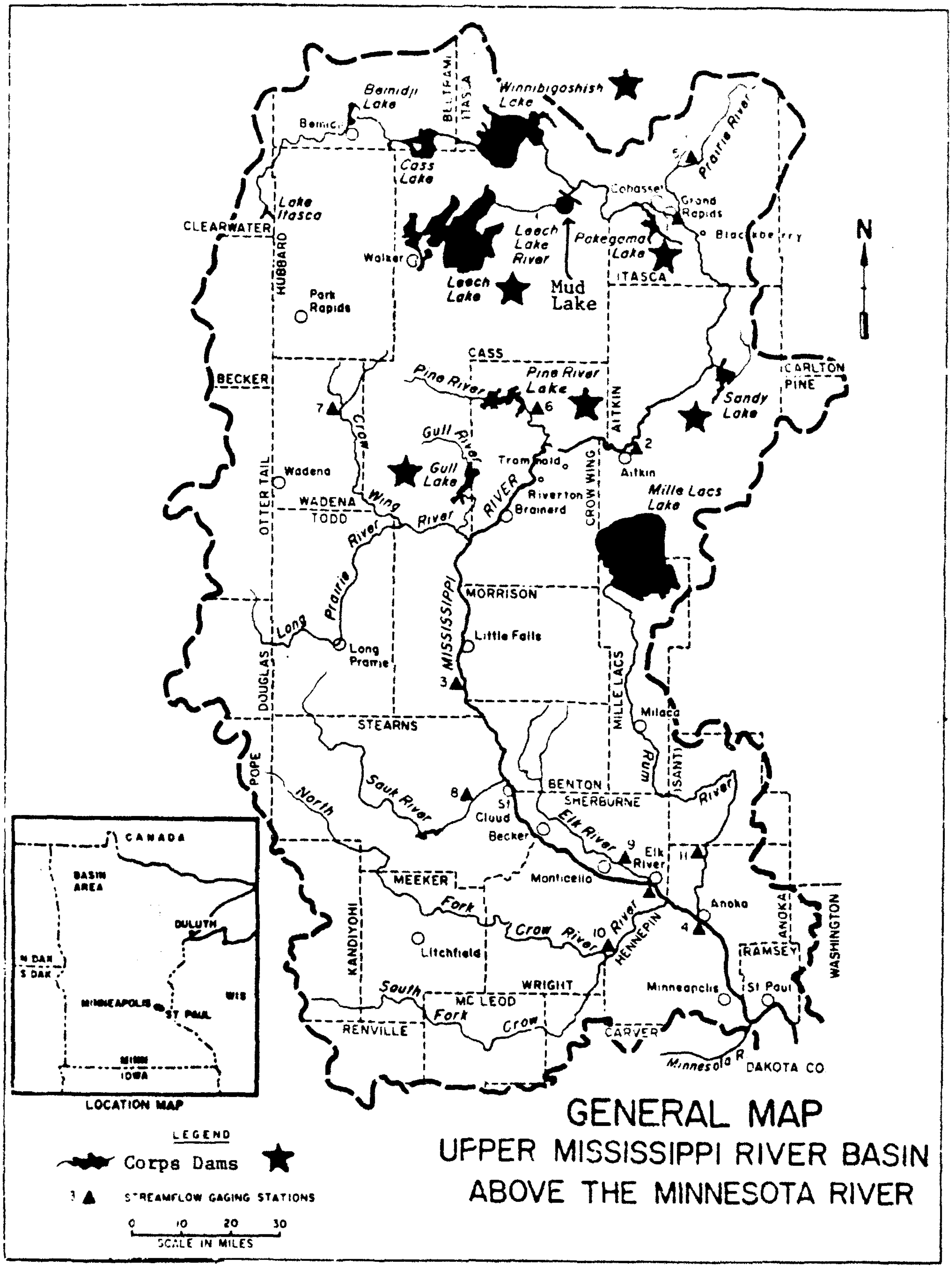
A drought action plan was prepared with the city of St. Paul during the 1982 Headwaters Feasibility Studies. The plan represents some informal understanding as to the city's operations during a drought. Under an extreme emergency, the city can stop withdrawals from the river for up to 60 days, using reserves, well fields, and storage in a lake system. The last page of the plan should be modified to clarify the State's role in water control for the headwaters lakes. See the Recommendations section of this report. No agreements exist with the City of Minneapolis.

PROJECT HISTORY AND LOCATION

In 1868, the St. Paul District Engineer, Major Gouverneur K. Warren, recommended a survey to ascertain "the practicability of forming large reservoirs on the headwaters of the Mississippi to aid in keeping navigation at low stages." Warren's later report of April 30, 1870, contemplated the construction of 41 reservoirs on the St. Croix, Chippewa, Wisconsin, and Mississippi Rivers. Further examinations were made during the 1870's, and the reservoir proposals attracted enough attention that on June 18, 1878, Congress approved and ordered the examination and survey of the headwaters of the Mississippi River.

Winnibigoshish, Leech, Pokegama, and Pine River, the first four dams authorized by Congress, were constructed between 1881 and 1886. With these four reservoirs in operation, it was determined that not all of the 41 reservoirs of the original plan were needed. A total of six dams were built on the Mississippi River and its tributaries. Sandy and Gull Dams were completed in 1895 and 1912, respectively.

Each of these structures is located at the outlet of a natural lake. These lakes are located in four north-central Minnesota counties: (1) Gull Lake in Cass and Crow Wing Counties; (2) Pine River Dam in Crow Wing County; (3) Big Sandy Lake in Aitkin County; (4) Pokegama Lake in Itasca County; (5) Leech Lake in Cass County; and (6) Lake Winnibigoshish in Itasca and Cass Counties. See the following general map of the Upper Mississippi River basin above the Minnesota River and the project map of the headwaters reservoirs.


GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN
ABOVE THE MINNESOTA RIVER
LEGEND
Corps Dams
STREAMFLOW GAGING STATIONS
0 10 20 30
SCALE IN MILES
LOCATION MAP
CANADA
BASIN AREA
DULUTH
N DAK
S DAK
MINNEAPOLIS
ST PAUL
WIS
MINN
IOWA
Bemidji Lake
Winnibigoshish Lake
Cass Lake
Lake Itasca
Leech Lake River
Pokegama Lake
Leech Lake
Mud Lake
Pine River Lake
Sandy Lake
Gull Lake
Mille Lacs Lake
Walker
Park Rapids
Cohasset
Grand Rapids
Aitkin
Wadena
Brainerd
Riverton
Little Falls
Long Prairie
Milaca
St Cloud
Becker
Monticello
Elk River
Anoka
Litchfield
Minneapolis
St Paul
CLEARWATER
HUBBARD
BELTRAMI
ITASCA
CASS
AITKIN
CARLTON
PINE
BECKER
OTTER TAIL
WADENA
TODD
CROW WING
MORRISON
MILLE LACS
DOUGLAS
STEARNS
BENTON
SHERBURNE
ISANTI
POPE
MEEKER
KANDIYOHI
WRIGHT
HENNEPIN
ANOKA
RAMSEY
WASHINGTON
MC LEOD
RENVILLE
CARVER
DAKOTA CO.
Prairie River
Pine River
Gull River
Crow Wing River
Long Prairie River
MISSISSIPPI RIVER
Rum River
Sauk River
North Fork Crow River
South Fork Crow River
Elk River
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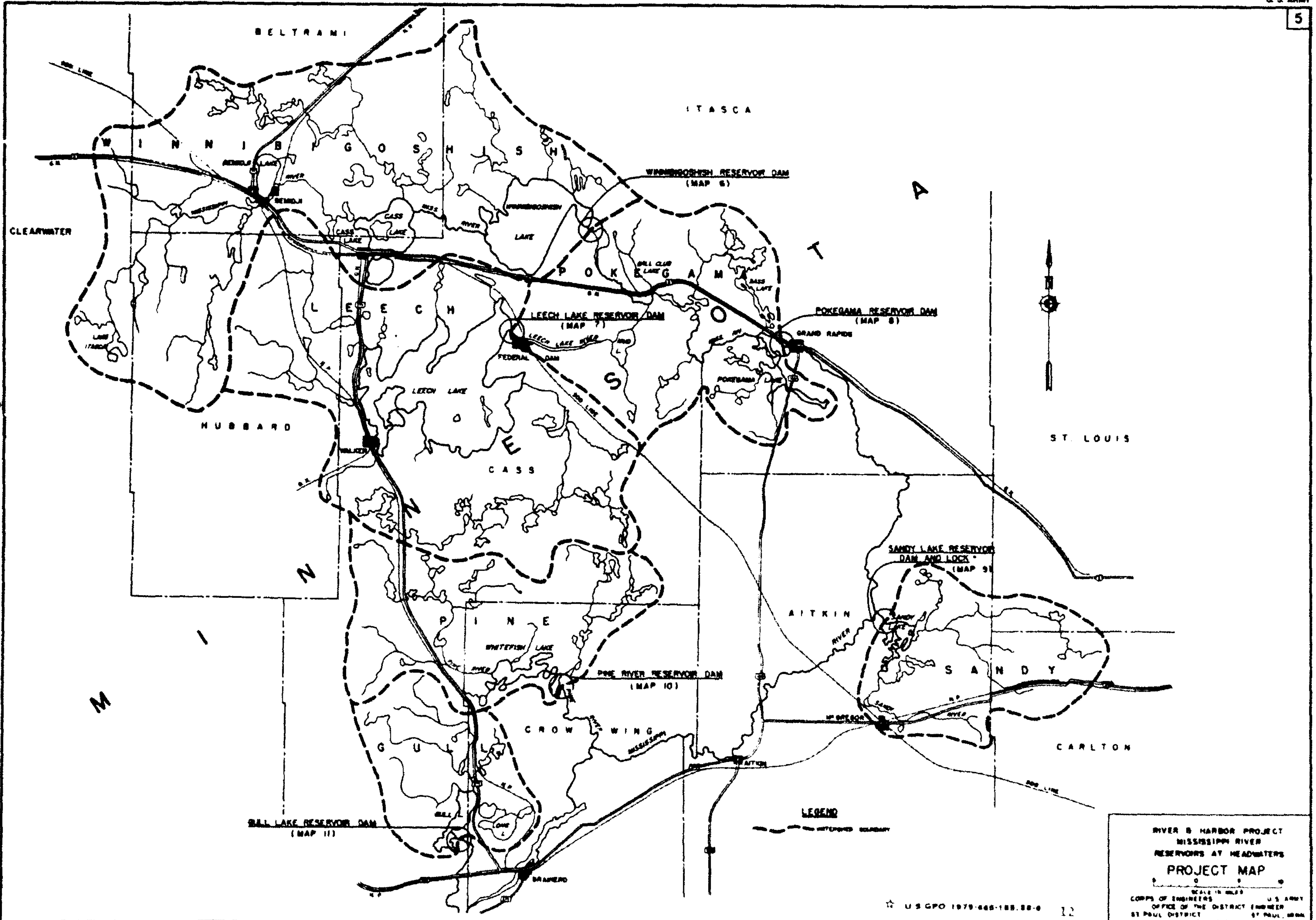


RIVER & HARBOR PROJECT
MISSISSIPPI RIVER
RESERVOIRS AT HEADWATERS
PROJECT MAP

CORPS OF ENGINEERS U.S. ARMY
OFFICE OF THE DISTRICT ENGINEER
ST. PAUL DISTRICT ST. PAUL, MINN.

☆ U.S. GPO 1979-666-188.88-6

DESCRIPTION OF ORGANIZATIONAL AND INSTITUTIONAL PROBLEMS

IDENTIFICATION CRITERIA FOR LOW FLOWS AND EMERGENCIES

The most difficult institutional problem encountered during a drought is to identify at what flow should cooperative actions begin. Low flows are complex because they can affect different water users in very unique ways. Each agency, community, business or citizen can have a different perspective concerning when action should be taken, and how much action is adequate to relieve low flow problems. One group can view a situation as an emergency, while another group sees the same situation as merely an inconvenience. Thus, it is helpful to plan in advance for specific flow conditions that everyone can agree will trigger certain actions.

In 1988, a Mississippi River flow of 1000 cfs at Anoka was identified by the Governor's Drought Task Force as a discharge that would trigger contingency actions. It was assumed that when the flow at the Anoka gage dropped below 1000 cfs for 72 hours, then it was too low for identified purposes in the Twin Cities area. The trigger flow level had to be assumed because inadequate information existed at that time to identify exactly the specific water needs in each part of the river. Since the 1988 low flow event, agencies have gathered information about water needs for the various purposes in each reach of the river. The followig paragraphs contain summaries of the information that has been collected. Also see the annotated bibliography for a list of recent publications by other agencies.

As a result of the 1988 drought, it was also recognized that more than one trigger is needed. Moderate low flows call for actions to protect and manage the aquatic life in the river. Severe low flows may cause an emergency, such as a shortage of potable water for human health and safety purposes. Each of these conditions can require very different actions by agencies and officials. Thus, a multi-step response plan is needed. As low flows decrease to specific trigger flows, then different actions are taken to respond. A summary of the specific stepped responses by the St. Paul District can be founa after the Executive Summary in this report.

AGENCY COORDINATION

Minnesota has not experienced many low flow events on its rivers such as occurred in 1988. However, over the years, other serious water resource problems have kept agencies and officials busy. As a result, detailed drought contingency plans have not typically been given high priority except perhaps to identify ways to reduce water demands in a shortage. The 1988 drought increased the priority for drought planning by many agencies with jurisdiction in Minnesota.

Agencies and officials had developed coordination networks to deal with floods and other emergencies that occur more frequently, but no similar network formally existed for drought emergencies. Thus, it was recognized that an agency coordination plan was needed to deal with the unique technical problems and public information needs that are encountered during a drought.

During the 1988 drought, meetings were held which involved a large number of public agencies, groups, and officials, including the St. Paul District. Of particular interest were a number of Drought Task Force meetings that were coordinated and led by the MDNR. The Task Force attendees willingly shared available information. Most early coordination efforts focused on determining the status of the developing dry conditions.

The group identified actions that might be taken to reduce water consumption and alleviate adverse instream environmental effects. The following table and figure shows the MDNR's suspension of water allocations in the Mississippi River basin upstream from the Minneapolis-St. Paul Metropolitan area.

LIST OF RIVERS WITH APPROPRIATION SUSPENSIONS IN 1988

River	Suspension Date	Agricultural Irrigation Permits: Number of Permits	Agricultural Irrigation Permits: Total Acres Authorized	Agricultural Irrigation Permits: 1987 Reported Acreage	Golf Course Irrigation Permits: Number of Permits	Golf Course Irrigation Permits: Total Acres Authorized	Golf Course Irrigation Permits: 1987 Reported Acreage	Other Appropriation Number of Permits	Total Authorized Pumping Capacity
Upper Mississippi River Watershed									
Elk	6/22/88	20	1480	811	--	--	--	--	10,950 gpm (24.3 cfs)
Rum & Trib. REINSTATED	6/29/88 8/18/88	8	580	176	4	213	93	1	5,950 gpm (13.2 cfs)
Sauk & Trib.	7/8/88	16	963	566	2	105	25	--	8,850 gpm (19.67 cfs)
Long Prairie & Tributaries	7/12/88	27	2425	1085	2	67	42	1	21,835 gpm (48.52 cfs)
Crow Wing & Tributaries	7/22/88	30	2134.5	640	1	26	26	2	17,430 gpm (38.73 cfs)
REINSTATED	8/17/88								
Crow River & Tributaries	8/1/88	13	839	418	3	98	88	2	9,030 gpm (20.07 cfs)

In 1988, a lack of information prevented the Task Force and individual agencies from an exhaustive evaluation of all alternative actions to supplement flows. As a result, discussions quickly focused on the Headwaters Project lakes. During future low flows on the Mississippi River, other lakes in the Headwaters area, such as Cass Lake and Lake Bemidji should also be considered as sources of supplemental low flow. The effects of the drought should not be concentrated in one area to diminish the effects in another. Further, coordination will be needed with the main stem dam owners from Grand Rapids to the Coon Rapids Dam to help minimize flow fluctuations that can result from daily operation of those dams.

The 1988 low flow on the Mississippi River emphasized the need for a more definite interagency coordination procedure. This may also apply to other basins in Minnesota, such as the Red River of the North or Minnesota River. Also needed are more specific triggering mechanisms for the procedure.

This should provide for earlier discussions about alternative low flow contingency actions and improved public information. Thus, it is recommended that the low flow plan for the Mississippi River Headwaters Lakes include an agency coordination procedure, described in Appendix D.

PUBLIC INFORMATION

As a result of other problems experienced during the low flow event, the District team members were afforded little time to consider public information needs. A number of public information meetings were held in the headwaters area in conjunction with Congressional, State, and agency representatives. A few media requests were handled by District team members, but the media's primary focus was on the perspectives of State officials and the reactions of headwaters area interests. District representatives were reluctant to publicly discuss the low flow problems because of a lack of information. As a result, the public became confused about which agency has water control authority for the headwaters project. A number of other public misperceptions or misstatements were also not responded to by the District. Thus, this low flow review has included preparation of a draft public information plan. The public information plan needs to be linked to the triggers of the agency coordination procedure so that the public can be informed about current project conditions and about actions that the District and other agencies might be taking to help. See Appendix D which includes the draft Public Information Plan and interagency coordination network.

IN-HOUSE DROUGHT MANAGEMENT ORGANIZATION

In 1988, no comprehensive in-house organization existed at the St. Paul District specifically for management of drought. A number of District offices have responsibilities for various aspects of a drought event, but no specific plan exists to trigger District-wide coordination of drought emergency duties. Emergency management teams do exist for other purposes, particularly for flood emergencies. It was proposed that an organization similar to the flood fight organization be planned for low flow emergencies. This in-house organization should also be responsible to help implement and participate in the Agency Drought Coordination Matrix.

The in-house drought management plan must specify who would be involved, each person's duties, and set out clearly defined triggers for their involvement. The plan should also describe how they would coordinate their efforts to provide timely information for decision-making by District executives. As a result of the 1988 drought and the problems that were experienced, an in-house drought management team has been designated. See Appendix D.

NONCONSUMPTIVE WATER USE AND INSTREAM FLOW NEEDS

9-FOOT COMMERCIAL NAVIGATION PROJECT

The commercial navigation locks on the Mississippi River require a certain amount of river flow to operate. The lock does not consume the water, but water is passed from upstream of the dam to downstream each time that a lock is operated through a complete cycle. Upstream water is used to fill each lock every time a barge goes through. The amount of flow needed for each lock to operate depends on how big the lock chamber is and how often it has to be operated to satisfy the barge traffic.

The Upper St. Anthony Falls (USAF) lock, located in Minneapolis, requires the largest volume of water for a single lockage. If the lock were to cycle continuously, as fast as safely possible, it would require about 700 cfs to operate. Fortunately, the USAF lock also has the least traffic of all the locks. Thus, it is estimated that about 350 cfs would provide adequate operation to handle current commercial navigational traffic. However, recreational boat lockages would have to be severely restricted or suspended in order to satisfy commercial navigation demand with 350 cfs.

A question arose in 1988 whether operation of the USAF lock would lower the pool level enough to expose the Minneapolis water intake. If the intake were to be exposed, it would not be able to draw water into the system, effectively stopping the inflow of water to the Minneapolis water supply system. The City of Minneapolis water intake is located on the river bottom, approximately 5 miles upstream from the USAF lock. The District conducted a hydraulic evaluation that indicates that the effects of

operation of the lock will travel up the river approximately 1 mile. Thus, the operation of the USAF lock is not expected to affect the level of water over the Minneapolis water intake. In 1988, city employees reported that the intake was dangerously close to being exposed. There may be some explanation for this other than operation of the St. Anthony Falls Locks. It is possible that operation of upstream dams may have caused a temporary shortage of flow and a resulting drop in water levels.

In 1988, another question arose whether the same river flow could be used to satisfy navigation and municipal water supplies, because the locks don't actually consume water. This is not possible because the water intakes for both the Minneapolis and St. Paul city systems are located upstream from the navigation system. The water required for municipal water supplies is removed from the river before it reaches the navigation locks. Thus, enough water must pass the city water intakes to operate the downstream locks.

In response to concerns about dissolved oxygen concentrations in the Mississippi River in 1988, the District provided small openings in gates and stop logs at St. Anthony Falls and locks and dams 1, 2, and 3 to provide some aeration. Aeration by this means is locally beneficial to aquatic life, but the overall effects on the dissolved oxygen levels in the river are minor. This technique might be used as long as higher priority demands are being met down to perhaps 750 cfs.

HYDROELECTRIC GENERATION PLANTS

Hydropower generating plants operate at lock and dam 2 at Hastings, lock and dam 1 at St. Paul, St. Anthony Falls at Minneapolis, St. Cloud Dam, Blanchard Dam near Royalton, Minnesota Power and Light at Cohassett, Sartell Dam, Little Falls Dam, and Grand Rapids, Minnesota. The hydropower plants make use of whatever flow is available to generate electricity. The amount of power generated is dependent on the amount of available flow. Extreme low flows would significantly limit or prevent hydropower production. The hydropower plants generate a relatively small amount of the power used in the area, but nonetheless are important generators of electricity from a renewable resource.

The hydropower dams are all generally operated as run-of-river, where inflow equals outflow, because of the need to maintain stable pool elevations upstream of the dams. However, the hydropower operators are allowed to fluctuate the upstream pools within specific restrictions. Under normal flow conditions, the restricted fluctuations generally do not cause significant percent changes in river discharge or problems for consumptive users or nonconsumptive users. Under low flow conditions, fluctuations of discharge from the hydropower dams can cause problems for downstream users. In Appendix C, river flow profile plots for July 28, 1988 and August 1, 1988 demonstrate how much flow fluctuations can be caused by the main stem dams in only 3 days. Further, uncoordinated operation of a number of the dams upstream of the Twin Cities has resulted in short-term decreases in river discharge during extreme low flow conditions, which exacerbate low flow problems and could conceivably uncover intake pipes for municipal supplies, electrical power generating plants, and other industrial users.

Further coordination is needed with the main stem and tributary dam owners. The MDNR the and the St. Paul District Drought team should coordinate with these dam owners according to the stepped - response plan in order to minimize temporary downstream flow shortages.

COOLING WATER AND THERMAL WASTE ASSIMILATION

A number of thermoelectric generating plants and industries make use of the Mississippi River for cooling steam condensors and machinery. The thermoelectric plants are of most concern because of their widespread effects on human health and safety and because they typically require significantly larger volumes of cooling water. The Northern States Power Company (NSP) Sherco and Monticello thermoelectric plants are located in freeflowing river reaches and require a river flow between about 200 and 250 cfs just to keep their intake pipes covered with water. More specific information is contained in Appendix I - Power Generation.

Thermoelectric plants also consume small percentages of the total volumes of cooling water withdrawn from the river. Makeup water is needed to

replace cooling water lost by evaporation. The exact consumption figures are contained in Appendix C - Consumptive Use Accounting.

The Minnesota Pollution Control Agency (MPCA) regulates the discharge of heated water back to the river by a permit system. The major thermal discharge on the river is at the NSP Monticello generating plant. The other thermal discharges are relatively minor in flow rate and size of the thermal mixing zones in the river. The Monticello plant has the capability for partial recirculation of its cooling water, but must cut back power production during periods of high water temperature, poor water quality and low flow. In 1988, the MPCA agreed to ease the thermal permit restrictions for the Monticello plant. However, NSP elected to stay within the permit limits and accept the consequential derates of up to 30 percent (165 megawatts) and purchase replacement power.

The NSP Sherco generating plant near Becker, Minnesota, is designed so that it must operate in a closed cycle... (total recirculating) mode all of the time. The Sherco plant requires a small amount of makeup water (Appendices C and I). Both Sherco and Monticello plants require a river flow of about 250 cfs just to cover their water intakes.

The MDNR regulates the cooling water withdrawals from the river with an allocation permit system. See Apppendix M. The Monticello plant is allowed to appropriate up to 645 cfs, but cannot withdraw more than 75 percent of the river flow. When river flows drop below 860 cfs, then the plant must recirculate a portion of the cooling tower discharge water to the condenser when the plant is at full load and appropriating water at the maximum rate. Power production may also need to be reduced in response to this regulatory constraint.

The 1989 Minnesota legislature changed the water use priority system, elevating power production to a number one priority along with municipal water supplies if they have a contingency plan.

Most of the power purchased by NSP because of low flow and high riverwater temperature conditions that caused a cutback in power production at the

Monticello plant in 1988 came from the Midcontinent Area Power Pool (MAPP) and cost each residential customer an additional $0.07 to $0.09 per week. NSP consciously took this contingency action to slightly increase charges to customers rather than further contribute to difficult environmental conditions in the river. Appendix I contains a letter from NSP to Congressman James Oberstar, dated July 26, 1988, that explains the basis for the decision. However, it is conceivable that the MAPP system might not have surplus power available during some future nationwide drought or there may be technical difficulties in the MAPP transmission system. Under those potential conditions, more drastic contingency actions would be needed, possibly including public requests by utilities and State officials for electricity conservation or use of MPCA and MDNR sanctioned variations from regulatory constraints. A more detailed discussion of NSP's contingency planning can be found on page 46.

MAPP's generation surplus status is critical information during low flow conditions on the Mississippi River. The MAPP Environmental Committee should be invited to coordinate status information. NSP holds daily strategy meetings to determine how they will meet daily peaks, including whether to purhcase power from MAPP. A roster of MAPP Environmental Committee members, revised as of March 1988, is contained in Appendix I.

WASTE ASSIMILATION

There are a number of municipal and industrial waste discharges to the Mississippi River, all of which are regulated under a permit system by the MPCA. Permits are conditioned to limit discharges of wastes to rates that can be assimilated readily by the river down to the 7-day 10-year low flow. When river discharge falls below the 7Q10 level, the ability of the river to assimilate wastes can be overtaxed, and water quality conditions in the river can deteriorate.

Municipal waste treatment along the Mississippi River has improved considerably to the point where now discharges rarely result in violations of stream water quality standards. Most of the waste effluents on the river produce only minor sags in dissolved oxygen downstream due to oxygen-demanding wastes, even during low-flow conditions. However, effluents from

three wastewater treatments plants and nonpoint agricultural sources in the Minnesota River can cause violations of stream water quality standards and can strain water quality conditions in the Mississippi River downstream of the confluence of the two rivers.

The Metropolitan Waste Water Treatment Plant serves most of the Twin Cities area. Its discharge of about 330 cfs constitutes a significant portion of total river discharge in lower pool 2 during low flow conditions. Treatment plant effluent quality, along with an algae bloom in pool 2, has allowed dissolved oxygen concentrations to remain high enough to support aquatic life in pool 2 during the 1988 low flow period, according to MPCA monitoring and Commission monitoring information. See Appendix J for further technical information.

WATER QUALITY IN THE MISSISSIPPI RIVER

Water quality conditions in the Mississippi River are strained by extreme low flows, continued waste discharges, and high water temperatures. Low discharges coupled with sufficient plant nutrients, low flushing rates in pooled portions of the river, and high water temperatures allow the development of dense blue-green algae blooms. The algae further modify water quality through day and night cycles of photosynthesis and respiration. A number of factors, such as high temperature, restricted habitat, overcrowding, increased unionized ammonia concentrations, algae toxins, high water temperature and fluctuations in dissolved oxygen concentration, can combine to impose great stress on fish and other forms of aquatic life. Stressed fish have reduced resistance to disease and can succumb to various pathogens and parasites. However, no significant fish kills were reported during the 1988 low flow event. See Appendix J.

Habitat for Aquatic Life

The amount and quality of river habitat are greatly affected by river discharge. As discharge falls, volume of available habitat is greatly reduced and habitat conditions change. Stream temperature increases as the river becomes shallower. Fish become overcrowded by reduced volume of habitat in the river and by influx of other fish from shrinking tributary

streams. Predation and angling pressure can become intense. Habitat conditions needed for early life stages of fish can actually improve during low flows. Some species, such as smallmouth bass, have improved recruitment during years with low flow. Extreme low summer flows in the Mississippi River are naturally occurring events to which most life in the river has adapted.

In the upper reaches of the river, stands of wild rice become inaccessible for harvest as river stage falls. Low river stages dewater backwater areas and riverine wetlands. Low water levels during the growing season have the positive effect of permitting germination of emergent aquatic plants and rejuvenation of wetland vegetation in succeeding years. See appendix E for further technical information on instream flow considerations.

Endangered Species

Low river flows tend to concentrate fish, increasing foraging opportunities for bald eagles. Low flows and related project operations have no other significant effects on endangered species.

Recreation

Water contact recreation, fishing access, and boating access are limited by reduced water quality and water depth as river discharge falls. Boat landings on free-flowing reaches of the river become unusable. Figures for economic loss of public use of the river would require considerable time and expense to determine. Thus, these economic losses were not estimated for 1988, and no information was gathered for future low flow situations. However, information about recreation benefits of the Mississippi River near the projects, within approximately 50 miles of the dams, would be helpful. It is recommended that the District consider obtaining more information, within study funding constraints.

It is assumed that some reduced base level amount of public use of the river would continue using the minimum instream flows that are available to the other higher priority uses in, and downstream on, the river.

In general, anglers reported good fishing during the 1988 low flow event because fish were concentrated. Future angling should benefit from a strong class-year of smallmouth bass recruitment as a result of the low flow event. Other fish species may be more difficult for anglers to catch during the next few years, until succeeding year classes of those species are recruited to the fishery.

NEEDS FOR WATER IN THE HEADWATERS LAKES

The headwaters lakes have limited inflows and increased evaporation during droughts, which can result in lake levels below the normal summer operating band. Essentially all uses of headwaters lakes water are nonconsumptive, where the demand is met by water remaining in the lake.

Recreation

The headwaters lakes support a major resort industry, thousands of private recreational cabins, and nationally renowned sport fisheries. Water levels in the lakes are important for aesthetic appeal, for the fisheries, and especially for small-boat access to docks and boat landings and through channels to other lakes and bays. Because recreational development on each lake has occurred in response to relatively stable summer water levels, any significant fluctuations in lake stage can cause considerable disruption of boating and associated recreational uses. However, overly stable lake levels may be counterproductive for some resources.

Chippewa Trust Resources

An 1855 treaty, later modified several times, reserved land, with associated natural resources, for the Chippewa people in the Headwaters lakes area. The treaty reserved specific lands from being ceded by the American Indians to the U.S. Government for purposes of providing homesteads for the Chippewa people. The reservations included the land, water and related resources necessary to fulfill the purpose of the reservation, that is to provide a moderate living standard for the Chippewa people. Resources that are important to the Mille Lacs and Leech Lake Bands are the lakes themselves and include fish and game, wild rice, and

bait fish. However, that list is not inclusive because both bands harvest many other resources associated with the Headwaters Project Lakes. The legal trust relationship predates the Headwaters Lakes project and the existence of Minnesota as a state.

The Winter's Doctrine, first formulated in Winters vs. United States, 207 U.S. 565 (1908) stands for the proposition that a reservation of lands for a homeland for an Indian Tribe implicitly reserved water necessary to fulfill the purpose of the reservation. Quantification of the amount of water needed and determination of the time during which it is needed is somewhat difficult and does not readily lend itself to exactness. However, through use of data which is being developed and with close consultation with and cooperation of the Tribal governments and representatives of the Bureau of Indian Affairs it is believed that in most, if not all cases, any supplemental releases can be executed in a manner to avoid interference with Tribal rights.

As stated in Cherokee Nation vs. Georgia, 30 U.S. (5 Pet)1, 8L.Ed.25 (1831), a unique relationship exists between the United States Government and federally recognized Indian tribes. Generally, the relationship imposes strict fiduciary standards of conduct on federal executive agencies in their dealings with Tribal governments. The United States District Court in Leech Lake Band vs. Herbst, 334 F. Supp 1001 found that the Minnesota Chippewa continue to hold aboriginal fishing, hunting and wild rice harvesting rights, that their rights were preserved by treaty, creating a guardian and ward relationship with the U.S. Government, and that the Treaty Trust rights had not been aborgated. The Corps of Engineers, as an Agency of the Federal Government is a party to such relationships and shall, to the best of its ability, strive to fulfill such obligations.

It should be noted, at this juncture, that the Tribes treaty rights with respect to the water are not paramount to the rights of the United States Government to the use of the water in aid of navigation.

The Treaty of 1837 contains provisions that also allow the tribes to hunt, fish and gather off-reservation. These provisions are for an area that

includes the Mississippi River along a significant reach between the project dams and the Twin Cities. The water control of the Headwaters Lakes project influences the productivity of the Mississippi River in this area, particularly within the first 50 to 75 miles downstream from each dam. The extent of project affects on the natural resources that the Treaty provides is discussed with the instream flows discussion in this report. The existing routine low flow plan appears to provide adequate flows for the riverine environment that contains these natural resources.

Thus, in controlling the Headwaters project dams, the District Engineer must consider the effects of water control decisions on these Treaty Trust resources, but navigation purpose is the highest priority.

Fisheries

All of the headwaters lakes support popular sport fisheries as well as species used for subsistence by the Chippewa people. Summer water levels affect availability of habitat for fish, especially shallow areas with aquatic plants that provide habitat for young-of-year fish. Lake stages may influence water quality (dissolved oxygen, temperature) to some extent, and the volume of suitable habitat available for fish. Water levels also affect the fishery through restrictions on boating access, as described above.

The Leech Lake and Mille Lacs Bands of the Minnesota Chippewa Tribe also commercially fish for whitefish and tullibee in Leech Lake and, Lake Winnibigoshish. Water levels on these lakes affect the production of these fisheries. Baitfish harvest is very sensitive to lake stage due to the behavior of the shiners, which concentrate in tributary embayments, and because of the depth restrictions imposed by the seining method of harvest. See Appendix L.

Wild Rice

The Chippewa people and many non-Indians harvest wild rice in the headwaters lakes. Wild rice is a protected plant under Minnesota Statutes and is regionally important as a source of income and subsistence. The

extensive wild rice stands on Leech Lake and Lake Winnibigoshish are reserved for harvest by the Leech Lake Band. Rice beds on Sandy Lake are harvested by the Mille Lacs Band and others. Other wild rice beds are located downstream from the project dams, such as, at Mud Lake and thus are also affected by project low flow operation. Lake stages affect wild rice in late summer by affecting boating access into the rice beds for harvest and by influencing the amount of wind blowdown, or lodging of plant stalks. If lake stages are too low to allow access into the rice beds by canoe, the wild rice cannot be harvested by the traditional method. The wild rice stands on the three lakes mentioned above are an economically and culturally significant resource for the Chippewa people. See Appendix L.

Wildlife

Lake stages affect fish-eating birds, waterfowl, and furbearers by influencing availability of food and denning and nesting conditions . Lower lake stages in late summer can positively affect fish-eating birds such as herons, osprey, and bald eagles by increasing the extent of shallow areas for foraging. Waterfowl can also benefit from slightly lower lake stages by increased availability of submerged aquatic plants. Furbearers, on the other hand, are negatively affected by lower lake stages because of drying out of their normal shallow habitat and stranding of dens. See Appendix L.

Water Quality

Water quality in all the headwaters lakes is good and generally is not significantly affected by lake stage. Low lake stages during late summer may drive the thermocline in some lakes or subbasins downward, possibly restricting the volume of habitat available for thermally sensitive species such as whitefish and tulibees. See Appendix L.

Shoreline Erosion

The shoreline of the Headwaters project lakes are subject to significant erosion at high lake levels. For example, at Winnibigoshish, high lake levels have eroded shores and caused damage to American Indian burial sites

and to lakeshore cabins and homes. Shoreline erosion also moves sediment onto fish spawning areas, covering the more ideal spawning substrate material. The covering of extensive areas of rocky lake bottom in Lake Winnibigoshish may be significantly reducing the productivity of the lake. A multi-agency group, lead by the U.S. Forest Service is seeking solutions to reduce shoreline erosion and related damages. Higher lake levels should be avoided in project lakes. Extended periods of low lake levels could erode normally inundated cultural resources sites. Minimizing lakeshore erosion is a recognized purpose under the "general public good" catagory.

Flood Control

The Headwaters Lakes Project also provides flood control benefit for the city of Aitkin. The lakes' levels are lower during the fall and winter in anticipation of spring snowmelt runoff. The spring run-off helps fill the lakes back to within the normal summer band of elevations. Flood control is a recognized project purpose under the "general public good" catagory.

Surplus Storage of Project Waters For Water Supply Purposes

The question arose during 1988 whether it would be useful to store more than usual volumes of water in the project lakes in order to have more water available for later release. This practice would conflict with the flood control operation of the lakes. It may also interfere with production of Tribal Trust resources, such as wild rice. If the lakes were intentionally held unusually high when a heavy rainfall occurred in the lake basins, then the lakes would rise to levels that could cause flooding and shoreline erosion damages.

One practice that is helpful during a dry winter is to not completely empty the routine flood control storage volume until an adequate snow pack is received in the lake basins to refill the flood control volume. This increases the chances that the levels of the lakes will return to at least the minimum summer elevations.

Consumptive Water Uses

To determine the low flow conditions of the Mississippi River, it is neccesary to consider the consumptive uses of water from the river. Consumptive uses are those for which water is withdrawn from the river, but not all is returned.

Consumptive uses of Mississippi River water include municipal and industrial supplies, irrigation, and industrial cooling such as evaporation from steam-electric generation. Consumptive use accounting considers these losses, as well as inputs (tributaries, groundwater, wastewater treatment outfalls) and returns (cooling water not lost to evaporation) to the river. Appendix C contains an approximate accounting, by reach, for July 27, 1988 to August 1, 1988.

This type of water use accounting is needed to determine whether a particular need might not be met. Before any emergency supplemental low flows might be discharged from the headwaters lakes project, a similar evaluation would be completed to verify that certain needs are not expected to be met. Further, because of the project authorization and Tribal Trust responsibility, it is not likely that emergency releases could be made to meet expected shortages of any of the consumptive uses, except those for human health and safety, such as human water supply. This is currently estimated to be 554 cfs (202 cfs water supply, 350 cfs navigation, 2 cfs NSP), measured at the Anoka gage.

In completing a future consumptive use accounting, the actual rate of water withdrawal for the various water uses along the river would need to be verified at that time. Appendix C contains a directory of the current major water users. The MDNR Water Allocation Unit should have the most current information when a consumptive use accounting is next needed. The unit would be requested to cooperate in the evaluation.

CORPS OF ENGINEERS WATER SUPPLY POLICIES

INTRODUCTION

The following policy information may change before the next serious low flow condition might occur on the Mississippi River. However, it is useful to summarize current water supply policies that apply to the concep'ual use of the headwaters lakes project for water supply purposes and those concerning emergency management capabilities of the Corps of Engineers.

EMERGENCY WATER SUPPLY

Public Law 84-99, as amended by Section 82 of Public Law 93-251, provides the Chief of Engineers with discretionary authority to provide emergency supplies of clean water, on such terms as he determines to be advisable, to any locality which he finds confronted with a shortage or contaminated water causing or likely to cause a substantial threat to the public health and welfare of the inhabitants of the locality. Work under this authority requires a request from the Governor of the State where the source of water has become unavailable or contaminated, and the work is normally limited to 30 days. This authority was used to supply Duluth, Minnesota, when it was found that Lake Superior water contained asbestos-like fibers. The authority does not extend to construction of permanent replacement water source or supply systems.

Public Law 95-51 further amended Public Law 84-99 to provide the Secretary of the Army authority under certain statutory conditions to construct wells and to transport water to farmers, ranchers, and political subdivisions that have provided a written request from within areas that the Chief of Engineers determines to be drought distressed. Corps assistance will be considered only when non-Federal interests have exhausted reasonable means for securing necessary water supplies, within the limits of their financial capability, including assistance from other Federal agencies, such as small business loans. Federally-owned equipment such as National Guard watertanks must be used to the maximum extent possible. Assistance can be provided to transport water for human and livestock consumption. The cost of transporting water is provided by the Corps; however, cost of purchasing

water is a non-Federal responsibility. In addition, assistance can be provided to construct wells, but Federal costs for well construction must be repaid.

PLANNING FOR MUNICIPAL OR INDUSTRIAL WATER SUPPLY

National water supply policy, defined by Congress, has been developed over a number of years and is still being clarified and expanded by legislation. This policy, as most recently articulated by Congress in the 1958 Water Supply Act (Title III of Public Law 85-500), recognizes a significant Federal interest in the long-range management of supplies, but assigns the financial burden to the users. Generally, planning and implementation of water supplies are a non-Federal responsibility, but the Corps of Engineers can provide planning and design services for single-purpose water supply projects at 100-percent non-Federal reimbursement. Water supply can also be included as a purpose of a new reservoir project. Section 22 of the Water Resources Development Act of 1974 provides limited Federal funding for planning assistance by the Corps of Engineers for the States.

EXISTING LOW FLOW PLAN FOR HEADWATERS LAKES

The existing water control plan for the headwaters lakes project contains a number of considerations for low flow operation of the project, including navigation, Tribal Trust resources, and an informal agreement with the Minnesota Department of Natural Resources for desirable low flow releases for downstream general public good purposes. The following paragraphs under (1.) summarize the existing water control considerations for commercial navigation and have been taken from 33 CFR 207.340(d). Chippewa Tribal representatives have suggested that the following Sections also define "surplus waters" as those not needed to sustain Tribal trust resources. However, that concept was not contained in the codified wording and thus can not be modified in this report, merely based on comment.

1. Authority of Officer in Charge of the Reservoirs. The accumulation of water in, and discharge of water from, the reservoirs, including that from one reservoir to another, shall be under the direction of the U.S. District

Engineer, St. Paul, Minnesota, and of his authorized agents subject to the following restrictions and considerations:

a. Notwithstanding any other provision of these regulations, the discharge from any reservoir may be varied at any time as required to permit inspection or, of repairs to, the dams, dikes or their appurtenances, or to prevent damage to lands or structures above or below the dams.

b. Except as provided in subparagraph 1(a) above, the average annual discharge from the respective reservoirs shall not be reduced below the following values, as nearly as they can practically be maintained.

Winnibigoshish	150	cubic	feet	per	second
Leech	70	"	"	"	"
Pokegama	200	"	"	"	"
Sandy	80	"	"	"	"
Pine River	90	"	"	"	"
Gull	30	"	"	"	"

c. During the season of navigation on the Upper Mississippi River, the volume of water discharged from the reservoirs shall be so regulated by the officer in charge as to maintain as nearly as practicable, until navigation closes, a sufficient stage of water in the navigable reaches of the Upper Mississippi River and in those of any tributary thereto that may be navigated and on which a reservoir is located. Extreme low flow conditions may require shortened hours of lock operation or other similar adjustments by the District Engineer.

d. Surplus waters in storage above the stages listed in paragraph 1(g), not required for use in the aid of navigation, as provided for in subparagraph 1(c) above, may be discharged at such time and at such rates

as will result, in the judgment of the District Engineer, in the greatest general benefit or the minimum of injuries to all affected interests.

e. No discharge other than the minimum specified in subparagraph 1(b) shall be permitted when a reservoir is at or below its minimum stage as set forth in subparagraph 1(g), except such increased discharge as may specifically be directed by the Chief of Engineers. The low flow agreement with the MDNR reflects this restriction by stepping the target low flows down until they are zero at these protected lake elevations.

f. The surplus inflow over the minimum discharge set forth in subparagraph 1(b) shall be stored until the limit of capacity or safety of the reservoir is reached, or until such time as water may be discharged in accordance with these regulations.

g. So far as practicable, under the requirements of these regulations, the officer in charge will cause the reservoirs to be maintained above the following minimum elevations, referred to zeros of respective Government gages:

Reservoirs	Elevation in feet above M.S.L. (1929 Adj)
Winnibigoshish	1294.94
Leech	1292.70
Pokegama	1270.42
Sandy	1214.31
Pine River	1225.32
Gull	1192.75

The range of fluctuations in levels in any reservoir in a single calendar year shall be held at a minimum consistent with the requirements of these regulations and with the inflow of that year.

2. <u>Section 21 of the Water Resources Development Act of 1988 (WRDA 88).</u> WRDA 88 requires that Congress be notified at least 14 days before project lake levels drop below specific elevations. See Appendix G.

3. <u>Treat Trust Relationship with The Minnesota Chippewa.</u>

4. <u>Low Flow Agreement with MDNR.</u> In addition to the Federal law just described, the St. Paul District has an informal agreement with the Minnesota Department of Natural Resources to make minimum flow releases for fish and wildlife and other general public good purposes during routine low flow periods. This informal agreement is based upon MDNR recommendations and defines the minimum daily releases to be made when the respective reservoir drops below an initial trigger elevation. If the reservoir level continues to drop, the minimum release will be cut in half once the level drops below a second lower trigger elevation. This release schedule is summarized in table 1. It should be noted that it has not been necessary to implement the reductions in release due to low lake levels called for in the agreement with the Minnesota Department of Natural Resources. In the future, drought coordination and planning activities may result in a very different drought operation strategy for the Headwaters dams than is contained in the existing agreement. The District Engineer has the authority to modify the low flow plan with proper NEPA coordination. It should also be noted here that the MDNR recommendations regarding minimum daily reservoir releases are followed to the extent that they do not conflict with the Federal requirements for minimum average annual discharges from the headwaters reservoirs. In most years, the volume of the spring snowmelt runoff is sufficient to meet the Federal requirement.

Table 1 - Headwaters Lakes Low Flow Agreement With MDNR

Reservoir	Minimum Daily Release (cfs)	Minimum Daily Release Trigger Elevation (1)	1/2 Minimum Daily Release (cfs)	1/2 Minimum Daily Release Trigger Elevation (2)
Winnibigoshish	100	1297.94	50	1294.94
Leech	100	1294.50	50	1292.70
Pokegama	(3)	1273.17	(3)	1270.42
Sandy	20	1216.06	10	1214.31
Pine	30	1229.07	15	1225.32
Gull	20	1193.75	10	1192.75

(1) Bottom of desirable summer range.

(2) Bottom of extreme regulation limit.

(3) Pokegama releases are limited to the sum of the discharges from Winnibigoshish and Leech Lakes.

PLAN FORMULATION PROCESS FOR SUPPLEMENTAL LOW FLOWS

INTRODUCTION

One of the conclusions of this report is that the available information indicates no overriding technical reason to permanently increase the specific discharge figure of the existing low flow plan. The plan apparently served reasonably well during low flow conditions in 1977 and 1988. However, it is prudent to consider that more difficult low flow conditions might occur in the future.

Of concern is the possibility that flow conditions lower than those in 1977 or 1988 might endanger human health and safety, such as insufficient potable water or electrical network brownouts (see Appendix I). Another concern is the possible adverse effects that extreme low flows might have on commercial navigation on the Mississippi River. In order to properly prepare for these concerns, the District must have a process to formulate and evaluate alternative plans for releasing emergency supplemental flows.

PLAN FORMULATION PROCESS

This report section is intended to emphasize the <u>process</u> that the District would use to identify the best method of making emergency supplemental low flow discharges from the project lakes. Because of the wide variations of physical conditions that enter the real-world decision-making process, the reader should not assume that any of the illustrative examples contained in this report are preselected for some future low flow event. In fact, it is likely that none of these examples would occur exactly as described because of the large number of variables to be considered.

PLANNING CONSTRAINTS

Many planning constraints limit the range of feasible methods of making emergency supplemental discharges from the project lakes. Constraints include, but are not limited to: physical limits of the dam to release water, length of time that it takes water to travel from the lakes to a needy reach, limited availability of information on project effes on Tribal

Trust and other resources, and amount of storage available in each lake. There are also institutional constraints including, but not limited to: water quality standards, laws, agency policy, and public acceptability. Most of these constraints will vary temporally and thus would need to be verified through coordination prior to responding to some future emergency.

PLAN FORMULATION RATIONALE

The first step in formulating alternatives for emergency releases from the headwaters lakes is to determine whether and how much total emergency flow is needed from the project. This includes consideration of sources of flow other than the Headwaters project lakes. In 1990, it is estimated that 554 cfs is needed at the Anoka gage. Discharges less than that constitute a human health and safety emergency. See the summary of the decision process following the Executive Summary at the front of this report.

In actual practice, an emergency need for supplemental flows in excess of the existing low flow plan would be extrememly rare. However, in the interest of documenting the emergency decision-making procedure, in the event that it might be needed, it is assumed for demonstration purposes that an emergency need has been identified for a total project discharge of 600 cfs, which would be 330 cfs more than is contributed by releases from the Headwaters Lakes under the existing low flow plan.

If and when a need for emergency supplemental flows is identified and the District Engineer decides to make the release, then the decision must also be made as to how best to make the release from each of the six project lakes. This decision-making process involves coordination and consultation with headwaters area interests, described in Appendix D, including Chippewa governmental representatives, resort interests, other dam operators and State, county, and local officials.

Some of the coordination topics include effects on commercial navigation, Treaty Trust resources, regional recreation benefits, the environment, and lake level recoverability. The Trust responsibility with the Minnesota Chippewa Bands requires special consideration, at a higher priority than that for the general public good purposes. The Treaty Trust related

resources include wild rice, fish, and game on Leech and Winnibigoshish Lakes. If emergency low flow releases are made that inhibit the use of Tribal Trust resources, then the damages will need to be assessed and compensation made for the damages. See Appendix L for more information on project effects on Trust resources. Appendix F presents a further discussion of the Treaty Trust relationship with the United States government.

There are many possible combinations of supplemental low flow discharges from the six lakes. For example, it may seem desirable to make releases so that all six lakes go down by the same amount. However, lowering all six lakes by an equal amount does not distribute the effects equally. Further, equity may not be the absolute objective, particularly in considering the Trust relationship with the Chippewa Bands. The point is that several alternatives will become obvious, based on existing lake conditions and the results of consultation with area interests. The job of the in-house professionals then is to formulate and evaluate those alternatives fairly and to ensure that they are really needed.

An important note is that, if the District Engineer determines to make emergency supplemental discharges, the routine low flow from any of the other project lakes should not be diminished. The aquatic life in the stream channels downstream from each dam will continue to require the routine low flow discharges. The supplemental flows, if needed, would be above and beyond the routine low flow discharge at any given dam.

In order to continue to describe this decision-making process, a number of alternatives and conditions must be assumed for illustration purposes. The District study team selected three example situations that are described in the next section. It should <u>not</u> be assumed that these illustrative examples have been preselected for any future conditions. Rather, the actual conditions of some future emergency would very likely require some solution different from the following examples.

DESCRIPTION OF ALTERNATIVES

The examples and their respective tables are illustrations of the type of information that would be presented in the actual plates during a real emergency. The following is a brief summary of the calculation methods used in determining the effects of various releases from the headwaters lakes in a low flow situation. A rain-free period was assumed for all three examples. It is also assumed that the withdrawal is planned to occur for a 90 day period, from July 1 to October 1. Plots of the expected lake level changes for each example over the 90-day period of analysis are available in Appendix B.

Example 1

All lakes are assumed to have a July 1 starting elevation equivalent to their respective low normal summer pool elevation. This elevation is then converted to its corresponding storage volume in acre-feet. From the storage value, evaporation losses are subtracted for the desired period to provide the option 1 line on each of the lake level graphs. The option 2 graph indicates the effect of evaporation plus the existing low flow plan. Option 2 represents the baseline or "without modifications" conditions from which to measure the effects of each example alternative. Option 3 indicates the effects of evaporation plus the existing low flow plan plus the emergency supplemental releases. The supplemental releases were calculated based on an equal drop in stage for each lake, resulting in discharges totaling 330 cfs.

Example 2

It assumed that the large lakes, Winnibigoshish, Leech, and Pokegama, have a July 1 starting elevation equivalent to their low normal summer pool elevations, while the smaller lakes, Gull, Pine, and Sandy, start at 1 foot below their low normal summer pool elevations. Emergency supplemental discharges are computed based on an equal drop in stage (0.20 foot) for each of the large lakes, resulting in total supplemental discharges of 330 cfs. The same procedure was followed as in example 1 for each day of the period. Gull Lake falls to its minimum pool elevation on July 1 and Sandy

Lake falls to its minimum pool elevation on August 18. The existing low flow operating plan specifies that, when minimum pool elevation is reached in a reservoir, then the normal low flow releases are reduced by one-half for that reservoir. Thus, minimum releases are cut in half for Gull and Sandy Lakes, reducing the combined project flow by 20 cfs. Therefore, in order to maintain the combined emergency and normal project low flows, an extra 20 cfs is released from Winnibigoshish Lake.

Example 3

The initial lake level condition is the reverse of example 2. The small lakes are at their low normal summer pool elevations, and the large lakes are 1 foot below their low normal summer pool elevations. Emergency supplemental releases are computed based on an equal drop in stage (1.16 feet) for each of the small lakes, resulting in discharges totaling 330 cfs. The same calculation procedure was followed as in example 1. Gull Lake falls to its minimum pool elevation on August 4 and Sandy Lake falls to its minimum elevation on August 21. After these dates, the minimum releases for Gull and Sandy Lakes are reduced by one-half, with extra releases made from Winnibigoshish Lake to compensate for the difference. For this example, additional releases are also made from Gull and Sandy Lakes (120 cfs and 84 cfs, respectively). These releases are eliminated once Gull and Sandy Lakes reach their respective minimum pool elevations; hence, the combined supplemental discharges total only 126 cfs. Therefore, to maintain the desired supplemental flow of 330 cfs, an extra 204 cfs was released from Winnibigoshish Lake. Winnibigoshish Lake was selected to supply the extra flows because, of the six lakes, it has the greatest storage and it is the farthest from reaching its minimum pool elevation.

EVALUATION OF ILLUSTRATIVE ALTERNATIVES FOR SUPPLEMENTAL LOW FLOWS

Project effects on resources are measured for each alternative water control plan and then are used to comparatively evaluate the alternatives. This section summarizes the process that would be used to evaluate the alternative means of making emergency supplemental releases from the headwaters lakes. The following paragraphs summarize the process for

individual project related resources. More detailed evaluation descriptions are contained in the appendices, as identified in each section.

BASELINE CONDITIONS

A baseline condition is needed from which to evaluate alternative changes from the routine low flow plan. The routine low flow plan is the "without alternative actions" condition. It is the baseline condition. Option 2 curves are the baseline conditions for the example lake level plots contained in Appendix B.

Consumptive Uses

Consumptive water uses, principally drinking water needs, would drive the decision on whether to make emergency supplemental releases. However, other lower priority consumptive uses would not be a significant factor in determining how much water is released from each project lake to meet the total supplemental need. The location of an emergency consumptive need might require special consideration of travel time from the project and may enter into the decision as to which lake would provide supplemental releases first. See Appendix C.

Lake Level Projections

Computer spreadsheets have been prepared to help predict lake level changes that would result from assumed releases. The spreadsheets can use inputs of historic inflows, precipitation and evaporation, the starting lake level, assumed duration, and the discharge that is to be evaluated. Predicted lake levels would then be used by the other team members to evaluate their expected effects on project related resources. The example evaluations assume that no rainfall would occur and that emergency releases would be required from July 1 to September 1. See Appendix B for example plots of projected lake level changes.

Lake Level Recoverability

Recoverability is the probability of refilling the lakes to normal levels during the water year following an emergency supplemental release. If a lake is unlikely to refill in the next year as the result of one alternative, another release plan might be considered or perhaps project effects on resources may also need to be evaluated for the following year. Reservoir recoverability considerations are based on stochastic evaluation of historic records. Prediction of future climatic cycles or trends, such as the Greenhouse Effect, are not involved. See Appendix B for a further description.

Recreation Resources

The headwaters area recreation economy can be affected by significant fluctuations in water levels of the six lakes. Lake level changes, particularly drops, can make boat ramps, harbors, docks, and connecting channels difficult or impossible to use by boaters. Thus, lower lake levels can reduce recreational use of project lakes and stress the dependent regional economy. See Appendix K. It was also found that inaccurate information about lake levels can be perceived as real by recreators and can cause actual reduced public use of the project area. The public information plan should provide ample accurate information about project conditions to the recreating public to help reduce induced stress on the regional economy. The Minnesota State Tourism Office should be contacted, in cooperation with the MDNR. See Appendix D for further description of the public information plan.

Chippewa Trust Resources

Effects on Trust resources require special consideration, different from consideration of the other project related resources. A description of the Treaty Trust relationship is found in Appendix E. Further information concerning project effects on individual in-lake Trust resources is contained in Appendix L.

Water Quality

Water quality in the lakes is typicaly quite good, but does deserve some additional monitoring efforts during unusual low flow conditions. Lake fisheries are dependent on good water quality. Downstream water quality effects under emergency low flow conditions would probably be related to thermal conditions at power plants and localized dissolved oxygen sags below water treatment plant outflows down to about Anoka. Water quality downstream of Anoka would be expected to be more dependent on factors other than supplemental flows from the headwaters project lakes. Water quality in Pool 2 should continue to be monitored Improved wastewater treatment facilities on the lower Minnesota River would contribute significantly to water quality in Pool 2 during low flow conditions. See Appendix J.

Instream Flows

The aquatic riverine habitat located immediately and for some distance downstream of the six headwaters project dams is highly dependent on continued low flow discharges from the dams. Some recreational use of the river, such as canoeing and fishing, is also dependent on the low flow discharge. The normal low flow plan makes valuable contributions to these instream flow needs. The effects of emergency supplemental flows on riverine aquatic habitat would also be beneficial, but would not typically be a significant consideration in determining how emergency releases would be made. This is because low flow discharges may continue in accordance with the normal low flow plan during an emergency release situation. Conditions should be monitored, however, in the event that further action is needed for instream purposes. See Appendix E.

Commercial Navigation

During extreme low flow conditions, emergency supplemental flows would help reduce lockage delays. Navigation requirements would be considered in the decision concerning whether and how much supplemental flow would be required from the headwaters project.

Power Generation

The NSP Sherco and Monticello power plants need 200 to 250 cfs to keep the power plant intakes covered. Emergency supplemental flows would help ease thermal restrictions on power generation. The power plant flow needs, particularly when there is no surplus enegergency available or brownouts, might enter into the decision on whether to release emergency supplemental discharges and how much to release, However, it is expected that emergency flow conditions at the 2 power plants would coincide with emergency flow conditions in the Minneapolis-St. Paul area. See Appendix I.

Recoverability and Storage Conservation

The potential length of any drought would be unknown. Thus, it is desirable to retain as much water in the headwaters lakes as possible for potential future emergency release, as needed. The no action plan (continue routine low flows) would reserve the greatest volume of water for future use. For all the options to release supplemental flows, it would be desirable to release as little water as possible to maintain the target emergency discharge. The statistical analysis of ability to refill the reservoirs in the next water year is known as recoverability. Recoverability would also be considered.

Cultural Resources

Any of the alternatives, including no action, would tend to lower lake levels and thus reduce shoreline erosion at identified sites. However, it is recommended that the known sites be monitored for erosion for any action. Lower lake levels would expose artifacts in areas that would normally be underwater. Thus, low lake levels might also encourage scavenging of artifacts located on the lake bottom at and below summer pool elevations.

COMPARATIVE EVALUATION DISPLAYS

It is most beneficial to display all of the results of the evaluations for each alternative on one table. This helps decision-makers identify significant differences between the plans. Tables 2, 3, and 4 display the evaluation results for the three example alternatives.

TABLE.2

IMPACTS OF EXAMPLE 1 - Supplemental Releases From All 6 Lakes (330 cfs) To Cause Equal Drop In Lake Levels; All Lakes Start At Bottom Of Summer ...

EFFECTS IN HEADWATERS LAKES AREA

I. Nonconsumptive Uses

Economic and Recreation Impacts:

Leech	$251,900	Reduction
Winnibigoshish	170,100	Reduction
Pokegama	35,100	Reduction
Gull	176,500	Reduction
Pine	82,100	Reduction
Big Sandy	26,400	Reduction
Total	$742,100	Reduction

Fisheries: Minimal adverse effects; monitor water temperature and dissolved oxygen

Wildlife: Minimal adverse effects; some positive effects

Wild rice: Percentage of access restriction = X percent on Leech Lake
Y percent on Winnibigoshish
Z percent on Big Sandy

Effects on harvest volume, determined in consultation with Tribes, would depend on season, prevailing price and actual production of wild rice in the subject year; statement on whether Trust responsibility would/would not be met for fish, wildlife, wild rice, etc. by the lake

II. Ability To Refill Reservoirs in Spring Sandy - No change (98%)
Pine - No change (98%)
Gull - No change (98%)
Winnibigoshish - No change (98%)
Leech - Change from 98% to 90%

III. Water In Storage For Extended Drought Equals surplus storage minus volume of proposed release rate over proposed release period.

IV. Social Effects Controversy minimized with forum for area input and use of public information plan.

V. Cultural Resources Lower water levels would likely reduce shoreline erosion at known sites.

EFFECTS ON DOWNSTREAM REACHES

I. Nonconsumptive Uses

Fisheries	Habitat limited physically, but improved somewhat, particularly reaches nearest dams.
Wildlife	Habitat limited by low river stage, but improved somewhat, particularly in reaches nearest dams; low flows have some positive effects.
Wild rice	Beds along river limited by low water levels, but improved somewhat.
Navigation	No limitations on lockages.
Water quality	Waste assimilation capacity of river strained; water quality conditions in pool 2 precarious and dependent on algal production of dissolved oxygen; no significant improvement until river discharge returns to about 3,000 cfs.
Hydropower	Plants operating at minimum capacity; strict run-of-river operation is encouraged.
Steam-electric cooling	Plants operating with maximum recirculation, Monticello at reduced generation levels to meet river thermal standards; supplemental flows should help ease thermal restrictions.

II. Consumptive Uses (See Appendix C.)

Water supply	Met, assuming enough of 330 cfs reaches location of need.
Industrial cooling makeup	As permitted by MDNR; thermal variance may also be needed from MPCA to minimize derates;
Industrial process	As permitted by MDNR.
Agricultural irrigation	As permitted by MDNR.

TABLE.3

IMPACTS OF EXAMPLE 2 - Supplemental Releases (330 cfs) From Leech, Winnibigoshish, and Pokegama Lakes To Cause Equal Drop In Lake Levels; Only These Lakes Start At Bottom Of Summer Band

EFFECTS IN HEADWATERS LAKES AREA

I. Nonconsumptive Uses

Economic and Recreation Impacts:

Leech	$251,900	Reduction
Winnibigoshish	170,100	Reduction
Pokegama	35,100	Reduction
Gull		No Change
Pine		No Change
Big Sandy		No Change
Total	$457,100	Reduction

Fisheries: Minimal adverse effects; monitor water temperature and dissolved

Wildlife: Minimal adverse effects; some positive effects

Wild rice: Percentage of access restriction = X percent on Leech Lake
Y percent on Winnibigoshish
Z percent on Big Sandy

Effects on harvest volume, determined in consultation with Tribes, would depend on season, prevailing price and actual production of wild rice in the subject year; Statement on whether Trust responsibility would/would not be met for fish, wildlife, wild rice, etc. by lake

II. Ability To Refill Reservoirs in Spring
Leech - Drop from 97% to 84%
Winnibigoshish - No change (98%)
Pine - No additional releases
Sandy - No change (98%)
Gull - No additional releases

III. Water In Storage For Extended Drought Equals surplus storage minus volume of proposed release rate over proposed release period.

IV. Social Effects Controversy minimized with forum for area input and use of public information plan.

V. Cultural Resources Lower water levels would likely reduce shoreline erosion at known sites.

EFFECTS ON DOWNSTREAM REACHES

I. Non-Consumptive Uses

Fisheries	Habitat limited physically, but improved somewhat, particularly reaches nearest dams.
Wildlife	Habitat limited by low river stage, but improved somewhat, particularly in reaches nearest dams; low flows have some positive effects.
Wild rice	Beds along river limited by low water levels, but improved somewhat.
Navigation	No limitations on lockages.
Water quality	Waste assimilation capacity of river strained; water quality conditions in pool 2 precarious and dependent on algal production of dissolved oxygen; no significant improvement until river discharge returns to about 3,000 cfs.
Hydropower	Plants operating at minimum capacity; Strict run-of-river operation is encouraged;
Steam-electric cooling	Plants operating with maximum recirculation, Monticello at reduced generation levels to meet river thermal standards; supplemental flows should help ease thermal restrictions.

II. Consumptive Uses (See Appendix C.)

Water supply	Met, assuming enough of 330 cfs reaches location of need.
Industrial cooling makeup	As permitted by MDNR; thermal variance may also be needed from MPCA to minimize derates.
Industrial process	As permitted by MDNR.
Agricultural irrigation	As permitted by MDNR.

TABLE.4

IMPACTS OF EXAMPLE 3 - Supplemental Releases (330 cfs) From Gull, Sandy, and Pine River Lakes To Cause Equal Drop In Lake Levels; Only These lakes Start At Bottom Of Summer Band;

EFFECTS IN HEADWATERS LAKES AREA

I. Nonconsumptive Uses

Economic and Recreation Impacts:

Leech		No Chagne
Winnibigoshish	$169,600	Reduction
Pokegama		No Change
Gull	643,800	Reduction
Pine	82,100	Reduction
Big Sandy	318,500	Reduction
Total	1,214,000	Reduction

Fisheries: Minimal adverse effects; monitor water temperature and dissolved oxygen

Wildlife: Minimal adverse effects; some positive effects

Wild rice: Percentage of access restriction = X percent on Leech Lake
Y percent on Winnibigoshish
Z percent on Big Sandy

Effects on harvest volume, determined in consultation with Tribes, would depend on season, prevailing price and actual production of wild rice in the subject year; statement on whether Trust responsibility would/would not be met for fish, wildlife, wild rice, etc. by the lake

II. Ability To Refill Reservoirs in Spring Leech - No change (55%)
Winnibigoshish - Reduced from 94% to 90%
Pine - No change (98%)
Sandy - No change (98%)
Gull - No change (98%)

III. Water In Storage For Extended Drought Equals surplus storage minus volume of proposed release rate over proposed release period.

IV. Social Effects Controversy minimized with forum for area input and use of public information plan.

V. Cultural Resources Lower water levels would likely reduce shoreline erosion at known sites.

EFFECTS ON DOWNSTREAM REACHES

I. Nonconsumptive Uses

Fisheries	Habitat limited physically, but improved somewhat, particularly reaches nearest dams.
Wildlife	Habitat limited by low river stage, but improved somewhat, particularly in reaches nearest dams; low flows have some positive effects.
Wild rice	Beds along river limited by low water levels, but improved somewhat.
Navigation	No limitations on lockages.
Water quality	Waste assimilation capacity of river strained; water quality conditions in pool 2 precarious and dependent on algal production of dissolved oxygen; no significant improvement until river discharge returns to about 3,000 cfs.
Hydropower	Plants operating at minimum capacity; strict run-of-river operation is encouraged.
Steam-electric cooling	Plants operating with maximum recirculation, Monticello at reduced generation levels to meet river thermal standards; supplemental flows should help ease thermal restrictions.

II. Consumptive Uses (See Appendix C.)

Water supply	Met, assuming enough of 330 cfs reaches location of need.
Industrial cooling makeup	As permitted by MDNR; thermal variance may also be needed from MPCA to minimize derates.
Industrial process	As permitted by MDNR.
Agricultural irrigation	As permitted by MDNR.

SELECTION OF EMERGENCY RELEASE PLAN

The next step in the decision-making process is to reverify the need for emergency supplemental low flow releases and to select one emergency supplemental low flow plan, implement and monitor it, as required. The selection would be made independently by the St. Paul District, in consultation with other interests and government officials, based on the findings of the stated evaluations. The three example plans for supplemental low flows described in this report are for three different conditions, and they cannot be directly compared. Thus, this report does not select a single alternative as the best, even for the assumed conditions. The District is concerned that, if one alternative were selected in this report, even for illustrative purposes, a reader might be misled to believe that a decision has already been made for some potential future low flow emergency. No decision has been predetermined, other than the general process by which such a decision might be made. Further, the process itself is flexible, to a certain extent, to provide for consideration of changed resources or newly discovered or modified project effects on the resources.

MEASURES TO MINIMIZE ADVERSE EFFECTS OF EMERGENCY SUPPLEMENTAL FLOWS

The primary means of minimizing impacts to the headwaters lakes is to delay supplemental releases from them for as long as possible and to provide supplemental releases only as necessary to meet the emergency need. The concern is also whether the effects would occur during the prime resort, fishing, and boating season and wild rice harvest. It is desirable to defer any release until after these seasons, if possible, and then to provide supplemental flow only as necessary to meet the identified emergency. This approach would further reduce the effects on headwaters lakes. The primary reason to delay making supplemental releases and to release only the amount needed, however, is that it is prudent to reserve water in storage in the event of a more severe and protracted drought.

To minimize impacts to cultural resources, shoreline areas at known cultural sites should be monitored for erosion. The low water conditions are likely to help reduce erosion of some high banks, but monitoring is

recommended. Some patroling may be needed to minimize scavenging of artifacts located at or below the summer pool band of elevations.
The MDNR shall ensure that all practicable water conservation measures are implemented by all water users concurrently with provision of any supplemental flows. The MDNR should also ensure that only appropriate and permitted rates of water withdrawals are taken from the Headwaters lakes and the Mississippi River between the headwaters and need areas. This could require restriction of lower priority permits. These measures are prerequisite for emergency low flow releases in excess of the routine low flow plan.

The District can take measures to increase aeration at metropolitan reach navigation dams. The State could consider requiring hydropower plants on the Mississippi River in the Twin Cities area to implement aeration measures. This could include curtailing generation and directing the flow to the spillway.

If traditional canoe access to wild rice beds for harvesting becomes restricted because of water levels, administrative authority exists to allow alternative techniques for harvest. However, it is recognized that the Leech Lake and Mille Lacs Bands do not support the use of nontraditional harvest techniques for in-lake wild rice beds. However, the Leech Lake Band does have a commercial wild rice operation west of Leech Lake, where they do use commercial equipment.

LOW FLOW PLANNING BY OTHERS

Long-Range Water Use Planning For the Twin Cities Area

Metropolitan Council

The Metropolitan Council is required (Minnesota Statutes, Section 473.155) to prepare short-term and long-term plan for existing and future water use and supply by February 1, 1990, and July 1, 1990, respectively. The plans must be submitted to the House Metropolitan Affairs Committee and the Senate Natural Resources Committee and be made available to the public. Consultation shall be with the Corps of Engineers, the Leech Lake

Reservation Business Committee, the Mississippi Headwaters Board, tne Minnesota Department of Natural Resources, and the Environmental Quality Board. The Council will also consult with other affected parties, including NSP, major water users and suppliers, Minnesota Pollution Control Agency, Metropolitan Waste Control Commission (MWCC), Minnesota Department of Health, and interested environmental groups. It is expected that the water supply planning efforts by the Metropolitan Council, in cooperation with the other identified agencies, will reduce, but not eliminate, the risk of emergency low flow conditions that might lead to supplementary low flows from the headwaters lakes project.

The minimum requirements for the two plans are contained in the legislation and include the following:

- update water supply and use information
- identify alternative courses of action during drought conditions
- recommend approaches to resolving water supply and use problems, including those that occur outside the region

Conclusions from the Short-Term Water Supply Plan for Metropolitan Council

The Metropolitan Council published a report to the State Legislature, dated February 1, 1990, entitled "Metropolitan Area Short-Term Water Supply Plan". The conclusions and recommendations from that report are as follows:

1. The approach outlined in this report to the legislature should be followed be all affected parties until a long-term water supply plan is developed and adopted for the Metropolitan Area.

2. To the extent possible, excess water flowing in the Mississippi River should be used as a primary source of water supply. The Minneapolis Water Works should continue its endeavor to locate a supplemental source of water because of uncertainties in the quality of the Mississippi River. In preparing a long-term water supply plan for the region, the Metropolitan Council should evaluate the feasibility of moving towards a regionally-

planned, locally-operated, water supply system that relies more on surplus surface water.

Groundwater should be used judiciously and supplement surface water supplies when surpluses are not available. The long-term water supply plan should define the conditions under which "surplus flows exist and examine alternative methods of using this surplus.

3. Major water users in the Metropolitan Area should first adopt a conservation approach to water use before looking for supplemental sources of water from outside of the region. Specifically, the matrix of response actions contained in Table 6 should be adopted and followed by the users at the respective trigger flows. Adoption of the plan by the appropriate parties should be mandated by the legislature. Municipal, industrial and commercial users not relying on the Mississippi River should prepare their own contingency plans for the conservation of water.

4. The Corps of Engineers and the DNR should formulate a cooperative arrangement with all of the operators of water control structures on, or adjacent to, the Mississippi River.

5. A critical flow level of 554 cfs (357 mgd) should be maintained at Anoka in order to meet the needs of surface water users in the Metropolitan Area, assuming they have begun conservation efforts. Attainment of this level of flow in the matrix (Table 6) will trigger the consideration of alternative sources of water, including a supplemental release from the Headwaters Reservoir system. (Editors note on the Metropolitan Councils conclusions and recommendations: The emergency actions by the Corps of Engineers are actually triggered by a National Weather Service 30-day flow prediction of less than 554 cfs at the Anoka gage. The Corp's emergency actions include the decision of how much water and how to release supplementary water from the 6 dams, as well as the timing of those releases, recognizing a 14 to 24 day travel time from the project lakes to the Twin Cities.)

6. The state of Minnesota through the DNR, and the region through the Metropolitan Council should continue efforts to coordinate drought response with the Corps of Engineers.

7. The Corps of Engineers and the DNR should proceed with their cooperative study of the in-stream flow needs of the Mississippi River and its tributaries. The MWCC and the MPCA should be involved in the evaluation in order to account for wastewater impacts on the river.

8. The Minnesota Department of Health (MDH), with the help of MPCA and the DNR, should study options for the reuse and reinjection of water from such sources as water treatment pump-outs, once through air-conditioning, and industrial non-contract cooling water. Agency policy allowing certain controlled water reuse and reinjection should be considered, based upon the findings of the MDH study.

9. The legislature should consider legislation requiring the adoption of major elements of the short-term drought response plan outlined in table 6.

10. A state drought management authority should be established in the State of Minnesota to respond to drought-related emergencies and to prepare a statewide framework for drought response. The Dnr is a logical choice because of its existing regulatory authorities. If the DNR is given expanded drought-response authority, a formal state advisory group or standing drought task force should established, consisting at least of the MPCA, the Metropolitan Council, the MWCC, the Mississippi Headwaters Board, NSP, and the cities of Minneapolis and St. Paul. This advisory committee would be expected to consult with the Corps of Engineers on matters pertaining to the Mississippi River. The drought management authority should establish a process for dealing with drought statewide and be given adequate resources to properly monitor the water resource inside and outside of the Metropolitan Area.

11. Minnesota Statutes, Chapter 105.417, should be expanded to include all major water users of both surface water and groundwater. No new appropriation permits should be issued by the DNR unless a contingency plan is prepared by the user. A time limit should be established within which

all existing permits will be reissued with the contingency plan requirement applied. The DNR should review its policy on allowing users to "accept the consequences" in lieu of preparing a contingency plan and the MDH should require a DNR approved contingency plan before issuing well approvals.

12. Alternative and emergency sources of water supply for the Metropolitan Area, including those sources evaluated in previous studies, should be re-evaluated on their social, environmental, economic and political impacts/relevance in order to update feasibility.

13. The long-term plan should evaluate the results of the latest USGS estimates of available groundwater and adjust the figures to represent the additional capacity lost to contamination. The plan should also define what level of withdrawal would be considered "optimal".

14. Following the second recommendation above, the plan should evaluate the long-term feasibility of developing a regionally planned water supply system that would, among other things, stress a more efficient use of surplus surface water and a shift from the unplanned use of groundwater; evaluate the feasibility of interconnecting municipal water supply systems in order to accommodate this shift in water use and provide emergency back-up for most suppliers, and examine how problems caused by the mixing of surface water and groundwater could be overcome; determine methods available to store and transfer surface water during periods of surplus river flow; and evaluate institutional arrangements and financial resources needed to undertake a regionally-planned supply system.

15. The economic implications of supplying a limited commodity (water) during a period of shortage should be examined. Among implications that need to be reviewed are how the cost of alternative supplies would be shared among users; how a system incorporating priority uses with the users' ability to pay and the need to keep the cost of water low could work; and how demand could be held down by raising the price of water.

16. Responsibilities of agencies planning water use and supply for the Metro Area, Greater Minnesota and state water planning activities should be clarified, with particular attention to those activities in the upper Mississippi River basin.

17. A water education program should be developed with a focus on "growth managers"--planners and decision-makers who guide the growth and development of the region. Public awareness efforts should also be the focus of educational programs carried out by both government agencies and water suppliers.

18. A detailed plan that aims to balance water availability with demand should be prepared, using statistics on the likelihood of obtaining water from various sources under differing climatic and demand conditions. In cooperation with the Corps of Engineers, the Metropolitan Council will continue to project the demand for water as the Metropolitan Area grows.

19. Proposed changes in the Federal Safe Drinking Water Act should be evaluated for their impact on the development of surface water and groundwater supplies. Specifically, the cost implications of treating one source versus the other should be examined.

20. The Metropolitan Council should collect and distribute information on effective water conservation techniques available to domestic, industrial and commercial users. It should also consider methods for implementing conservation of water in the region, including introduction through a mandatory state building code.

21. The Metropolitan Council should work with the MWCC and the MPCA to assure that a maximum cooperative effort is made to maintain good water quality in receiving streams during periods of extreme low flow.

22. Municipal water suppliers should be surveyed to determine the price they charge for water, the amount of commercial/industrial use of municipal water and the occurrence of well problems.

Mississippi River Main Stem Dam Owners

The main stem dams at Blandin, Blanchard, Sartell, and St. Cloud can cause low flow interruptions or surges that have caused difficult water control problems for downstream water utilities and power generation plants, particularly during low flow events, such as those in 1977 and 1988. The main stem dam operators typically seek to stabilize their pool levels, accentuating the fluctuations in river discharges downstream from the dams. However, under emergency and extreme low flow conditions, it is desirable that their operation minimize river flow fluctuations. Such flow fluctuations should be minimized when flows at Anoka are less than about 1000 cfs. This would contribute to stable flow conditions and minimize the risk of short-term shortages at downstream water use points.

The Federal Energy Regulatory Commission (FERC) has primary jurisdiction over licensing hydropower facilities on the Mississippi River. Hydropower licenses are also subject to periodic review and update by FERC. The MDNR also has certain authorities over the mainstem dams, including water use allocation permits and the dam safety program. However, the MDNR and District Drought Coordinator should cooperatively seek voluntary compliance of the mainstem dam operators. Carefully coordinated low flow operation of the main stem dams would tend to minimize the temporary low flow fluctuations that have occurred during past extreme low flows on the Mississippi River.

The mainstem dams are typically operated in a run-of-river mode. However, the term "run-of-river" has many definitions. During extreme and emergency low flows, it should be defined as inflows exactly equal outflows. This is very difficult to do with smaller pools, such as these, and may require significant additional effort on the part of the dam operators.

Headwaters Area Dam Owners

Initial meetings have taken place between dam owners in the headwaters the Mississippi Headwaters Board area and the St. Paul District to discuss how to improve water control coordination, including coordination during low flow events. The dam owners include the Corps of Engineers, the Otter

Tail Power Company, the MDNR, Blandin Paper Company, and the U.S. Forest Service. When completed, this planning would help to ensure that adequate low flows would be released from each dam to provide for the survival of the aquatic environment in the streams downstream from each of the dams. The MDNR has administrative responsibility to set low flow target discharges for dams and protected discharges in rivers downstream from them. The Federal dam operators normally cooperate with the MDNR efforts to the greatest extent practicable in meeting the low flow discharge targets.

City of St. Paul Board of Water Commissioners

The St. Paul water utility officials prepared their Drought Action Plan in cooperation with the Corps of Engineers during the Corps Headwaters Feasibility study that was concluded in 1982. The St. Paul Drought Action Plan should be updated to reflect the results of this low flow review. The last page of the plan should be clarified to indicate that the Minnesota Governor requests supplementary releases from the headwaters project if emergency conditions are projected by his drought task force. It is the St. Paul District Engineer who would decide whether and how emergency releases might be made from the headwaters lakes project. Further, the table of projected flow needs in the Mississippi River for water supply purposes is outdated and does not reflect the dynamic nature of future conditions that might lead to a water supply emergency. It is suggested that the table of projected flow requirements be deleted.

ACTIONS BY OTHER AGENCIES

The MDNR has authority over water control structures and water use in Minnesota. Under certain low flow conditions, the MDNR can prohibit irrigation withdrawal from surface waters that flow into the Mississippi River upstream from Minneapolis-St. Paul. More extreme low flow conditions might cause the MDNR to consider suspension of water withdrawals by other classes of permittees to meet the highest priority needs. The main operators of stem dams located between the headwaters lakes and Minneapolis-St. Paul should be encouraged by the MDNR and District to minimize flow fluctuations during restrictive low flows.

The State owns, under MDNR management, several abandoned mine pits in the headwaters region that contain considerable volumes of water. Pumping from these mine pits was considered to supplement river low flows, but costs were assumed to be prohibitive. It is suggested that this alternative be explored further by the MDNR as a possible alternative means to provide river flow supplements. The District could provide limited technical assistance for design and cost estimates, if needed by the MDNR.

The Minnesota Pollution Control Agency regulates the use of State waters for waste assimilation. We assume that the MPCA enforces all practicable measures that would reduce waste discharges and improve water quality. This is a critical element of dealing with low flow conditions.

After the low flow event in 1977, the city of St. Paul prepared a drought action plan and developed alternate water sources. The alternate sources include additional impoundment volume in system lakes and additional wells have been drilled. Thus, St. Paul has a stepped drought action plan to implement in the event of low flows on the Mississippi River.

Following the 1977 low flow event, the city of Minneapolis also began drought planning and looking for alternate sources. The primary design parameter is that the emergency source should provide a minimum of 50 million gallons per day (mgd). This was estimated based on achievable water conservation by banning outdoor water usage for sprinkling and other activities, coupled with an intense public appeal for curtailment of consumption.

In 1978, Minneapolis hired a consultant to study a shallow aquifer well system in their intake plant area on the Mississippi River. Unfortunately, the study showed that this area was isolated to the east and south by impermeable layers and the groundwater recharge of the proposed area was not adequate to sustain the 50 mgd. Also deep wells alone were dismissed because they would not supply 50 mgd. As a consequence, the city then budgeted for an expanded study involving FMC property just north of the intake plant area. However, before the study could begin, the issue of groundwater contamination emerged in December 1981. The contamination is

being cleaned up, but water from the area's shallow aquifers would require the use of expensive activated carbon treatment for the foreseeable future.

Thus, the city shifted its scrategy to a combination of deep and shallow wells to obtain the needed 50 mgd. To this end, the city engaged with the U.S. Geological Survey (USGS) in a jointly funded 3-year study of the northern metropolitan area. The goal is to determine the inter-relationship of the shallow aquifers with city lakes, streams, and the Mississippi River. The study results will provide some design parameters for the contemplated system of shallow and deep wells that would have the least impact on the total water system in the metropolitan area, yet provide Minneapolis with the required 50 mgd. The USGS study is scheduled to be completed in 1989. The report should help the city of Minneapolis and Met Council in some further alternative scoping and analysis This may lead to a reduced probability of need for future emergency releases from the headwaters project, but probably not for at least 5 to 10 years.

The Minneapolis Emergency Preparedness Office has initiated a water supply vulnerability assessment to determine the risk of contamination of the existing supply system. The results could lead to actions to reduce the risk or at least increase the understanding of the level of risk of accidental contamination of the Mississippi River upstream from the Minneapolis intake.

In 1988, Northern States Power Company voluntarily reduced power generation at the Sherco and Monticello plants located on the main stem of the Mississippi River. NSP replaced the required generation capacity with power purchases from MAPP, their reliability network of utilities. MPCA offered to allow NSP to exceed thermal assimilation requirements of their discharge permit. NSP declined to exceed the permit standards. If replacement generation capacity had not been available from MAPP, then NSP might have needed to exceed the permit standard, in cooperation with the MPCA offer.

In 1988, the St. Paul District conducted supplemental aeration of flows passing through the St. Anthony Falls navigation strcutures and locks and dams 1, 2, and 3. Aeration is provided by cascading flows over spillways,

through lock filling conduits, and by operations of bubbler systems. The purpose of the supplemental aeration was to help maintain water quality conditions needed for aquatic life in the nearby reaches of the river. This action was initiated in 1988 in response to a request by the MPCA, and these measures were continued only as dissolved oxygen conditions required.

FUNDING FOR IMPLEMENTATION OF CONCLUSIONS

The following conclusions and recommendations concern the desirability of obtaining and developing additional information related to the Headwaters Lakes project. The information described in each conclusion or recommendation would enhance the decision-making for low flow water control for the project. However, the work items described in each conclusion or recommendation will be scheduled, only as the availability of funding permits, in accordance with District priorities and subject to the availability of the recommended cooperating agency personnel.

CONCLUSIONS AND RECOMMENDATIONS

1. Water control authority for the Headwaters Lakes project has been delegated to the St. Paul District Engineer, through the Secretary of the Army and the Corps of Engineers chain of command, from the Congress of the United States of America, within specific Federal and Treaty Trust constraints. The Congressional authority for the project does not specifically provide concurrent water control authority to the State of Minnesota, but the State's concerns are routinely considered. The Headwaters project dams are operated to be used first for the authorized navigation purpose, second for protection of Treaty Trust resources, and third for "general public benefit or to minimize injuries."

2. A Trust relationship exists between the United States and its agencies, including the Corps of Engineers, and the Minnesota Chippewa Tribe to protect aboriginal and treaty rights to waters that are necessary to fulfill the purpose of the treaty created reservations. Such rights include, but are not limited to, that quantity of water needed for the production and harvest of wild rice, fish, and game needed to achieve a moderate standard of living for reservation members.

3. It is concluded that there is no overriding reason identified, at this time, to increase discharge figures for the routine low flow plan for the Headwaters Lakes. This plan is subject to change, as relevant conditions change. The routine low flow plan, including the emergency low flow plan, can be adjusted by the District Engineer at any time, after considering its effects on commercial navigation and Tribal Trust resources, and satisfying the NEPA decision and public notification process. Although the project existed prior to passage of NEPA, changes to the project must be accomplished in accordance with its requirements. One of the principal reasons that the normal low flow discharges might be changed in the future is to better contribute to instream needs for aquatic life in the downstream river reaches located closest to the six project dams. However, the recent instream analysis, completed with existing data in cooperation with the MDNR, did not include the river reaches that are most affected by the project because the only readily available cross-section data was located between St. Cloud and Elk River. See pages E-15, E-16 and E-17.

4. It is recommended that the MDNR and St. Paul District cooperate to complete instream flow needs analysis at selected river reaches that are closer to the project dams and thus are most affected by the normal low flow plan of the Headwaters project. The MDNR has authority to evaluate and establish low flow target discharges for the protection of instream aquatic habitat. The Minnesota Chippewa support this work because low flows also help support Treaty Trust resources. Northern States Power indicates a willingness to provide technical assistance for instream flow work on the Mississippi River. Results of this recommended instream work may indicate a need to reconsider the discharges of the normal low flow plan. See pages E-15, E-16 and E-17.

5. The routine low flow plan has been clarified to include a stepped decision-making procedure for the St. Paul District to implement its role in the Agency Drought Coordination Matrix. A summary of this decision-making and response procedure follows the Executive Summary, located at the beginning of this report. The drought response activity would intensify as low flow conditions worsen, possibly leading to activation of a complete in-house team to evaluate the need for and effects of alternative contingency actions, such as emergency supplemental releases from the Headwaters Lakes. The decision-making procedure includes consultation with

the Minnesota Chippewa Tribe and Bands and the BIA at specific times. The recommended drought response procedure includes a public information plan to seek public input to the stepped response process and to inform the public of the status of the drought response activity and project conditions. Also see Appendix D.

6. Use of the Headwaters project discharges to supplement low flows, at rates of release greater than the routine low flow plan, was considered in the 1982 Headwaters Feasibility Report. The report concluded that low flow supplements appeared to be economically feasible. However, the consideration of supplemental low flows is not purely economic, particularly when considering Treaty Trust responsibilities. The 1982 feasibility report recommended, on page 222, that low flow supplements not be adopted as normal practice, but might be used on an emergency basis. The Minnesota Chippewa and Headwaters area public are concerned that the first occurrence of emergency supplemental releases would be precedent setting and might lead to downstream long-term dependence on supplemental flows for other than emergency needs.

7. The District recommends and supports efforts by cities that are dependent on the Mississippi River for municipal water supplies to develop alternative water supply sources and conservation techniques. These measures would not only provide an added margin of dependability of water supply systems during low flow conditions, but would protect the cities in the event of unexpected water quality problems, such as from a chemical spill or some other unforeseen incident. Particularly, we support the City of Minneapolis' efforts to complete a risk assessment, the USGS groundwater study, and any other efforts in working toward an alternate source.

8. The Metropolitan Council's recommendations to the Minnesota Legislature, dated February 1, 1990, concerning water supply for the Twin Cities metropolitan area are expected to reduce the dependence of the Twin Cities area on the Mississippi River during low flows and reduce the risk of needing emergency low flow releases from the Headwaters Lakes project for municipal water supplies. The St. Paul District supports the water supply planning efforts of the Metropolitan Council by cooperating with the Metropolitan Council and State officials in the use of the IWR-MAIN water

use forecasting model, using Section 22 funding for District participation. It is further recommended that the IWR-MAIN model be considered for any other cities that rely, at least partially, on surface waters of the Mississippi River basin for municipal water supplies.

9. It is recommended that the MDNR and St. Paul District cooperate to assist the operators of dams, located in the basin upstream from Anoka, to prepare low flow water control plans that contribute to stable river flows downstream from the dams. Contacts would be needed during preparations for an incipient emergency low flow condition. See paragraph 7.5 of Appendix E. The St. Paul District will continue to participate in preparing water control coordination procedures among Upper Mississippi River dam owners, to include low flow coordination.

10. It is recommended that the MDNR and St. Paul District cooperate to incorporate the results of this low flow review, and its recommended further actions, into the MDNR's Drought Contingency Plan.

11. Based on comments provided by the St. Paul District, the St. Paul Board of Water Commissioners is considering modification of their Drought Action Plan, including the last page to clarify that the St. Paul District Engineer would decide the magnitude of emergency releases and how they might be made. The District's comments also stated that the city's plan should recognize the Minnesota Department of Natural Resources as the primary contact for water restriction and other information, rather than the Corps of Engineers, as the original plan states. Further, the District requested that the table of projected flow requirements to meet water supply needs be deleted as it is outdated and does not reflect the dynamic nature of future conditions that might lead to a water supply emergency.

12. The Upper Mississippi River Basin contains lakes, reservoirs and surface water bodies, other than the 6 Headwaters project lakes, that could also contribute to low flows on the Mississippi River and its tributaries. It is recommended that the MDNR and responsible entities for the other water bodies cooperate, in coordination with the St. Paul District if needed, to determine reasonable routine low flow discharges for these surface water bodies. Further, it is recommended that, during this work,

contingency actions also be identified for each water body for possible emergency supplemental low flow discharge purposes.

13. The St. Paul District has expanded its water quality monitoring program to include each of the 6 Headwaters project lakes. Basic limnologic water quality monitoring is being conducted on a weekly schedule during open water season. Profiles of water temperature and dissolved oxygen concentrations within each lake and lake subbasin would permit the evaluation of the effects of declining lake levels on water quality of the project lakes. Thus, the effect of project water control on in-lake resources, related to basic water quality parameters, could be evaluated. See Appendix L.

14. It is concluded that the routine low flow plan be modified to include gradual discharge changes at all 6 dams during low flows, to minimize negative effects on downstream aquatic resources.

15. It is concluded that emergency conditions, under which emergency supplemental low flows would be released from the Headwaters project lakes, is defined to mean when the discharge is less than 554 cfs (350 commercial navigation, 202 restricted municipal water supply and 2 NSP), measured at the Anoka gage. It is recognized that this discharge figure can change over time. However, the District will not recognize an upward adjustment of this figure without first consulting with the Minnesota Chippewa Tribe and Mille Lacs and Leech Lake Bands.

16. It is recommended that the Minnesota Chippewa Tribe, Leech Lake and Mille Lacs Bands, BIA and St. Paul District cooperate to identify additional information that would contribute to an improved understanding of project low flow water control on Tribal Trust resources. The Minnesota Chippewa Tribe, both Bands and BIA indicated in their conjunctive comments that, in their opinion, additional information is needed to properly understand the effects of project low flow water control on Tribal Trust resources.

17. The St. Paul District does not support the use of Mississippi River flows for augmentation of lake levels in the Minneapolis-St. Paul

metropolitan area for recreation and aesthetic purposes, particularly during low flows on the Mississippi River. The District's concern is that the use of Mississippi River low flows to augment metropolitan area lakes might increase the risk of needing emergency low flow supplements from Headwaters project lakes. However, the District supports use of offstream storage of excess Mississippi River flows for water supply purposes during emergency and low river flows.

18. It is recommended that the City of Minneapolis (and those cities dependent on Minneapolis) decrease their dependence on Mississippi River flows for water supply purposes during shortages of river flows. The District supports the Metropolitan Council's concept of using Mississippi River flows when they are in excess, but then switching to groundwater during emergencies and low flows. If implemented, such features would reduce the risk that emergency supplemental low flows would be needed from the Headwaters project lakes.

19. It is recommended that the St. Paul District cooperate with State officials to consider the need for low flow planning and Corps of Engineers project water control reviews for other river basins in Minnesota, North Dakota, and Wisconsin and to scope any needed planning efforts and to program funds for such reviews. This is needed particularly in the Red River of the North basin.

20. An analysis is needed of reservoir water level effects on natural resources by elevation, duration, and time of year to be conducted. Specific management goals must be defined for natural resources of the Headwaters Lakes. Then, an optimized strategy for Headwaters Lakes operation could be developed using a multiple reservoir system optimization model.

Roger L. Baldwin

26 Oct 90
Date

Roger L. Baldwin
Colonel, Corps of Engineers
District Engineer

ANNOTATED BIBLIOGRAPHY

Low-Flow-Frequency Characteristics for Continuous-Record Streamflow Stations in Minnesota, dated 1987, published by the U.S. Geological Survey (Water-Resources Investigations Report 86-4353), prepared in cooperation with the Minnesota Environmental Quality Board and the Minnesota State Planning Agency, through the U.S. Army Corps of Engineers and the Minnesota Department of Natural Resources.

Water Resources Issues in the Metropolitan Twin Cities Area: Planning For Future Droughts and Population Growth, Summary of a Workshop, October 25, 1988, dated April 1989, by the Minnesota Water Resources Research Center, University of Minnesota. The publication contains descriptions of: meteorologic aspects of the drought; water uses and needs; Minneapolis and St. Paul city water supply systems; regulatory aspects; alternatives for Twin Cities water supplies; and Headwater area water uses and interests.

Drought of 1988 dated January 1989, published by the Minnesota Department of Natural Resources, Division of Waters. This reference contains information concerning the statewide effects of the drought; streamflow, lake level and aquifer level records; state allocation actions; recommended drought planning work and legislative initiatives and a record of National Weather Service 30-day predictions for discharges at the Anoka gage.

Documents Related to Tribal Rights in the Mississippi Headwaters Area: An Annotated Bibliography dated February 1, 1989, by David J. Siegler, Attorney at Law, Ashland, WI, Contract Number PD-ES-88-470, St. Paul District, Corps of Engineers, Department of the Army.

Metropolitan Area Short-Term Water Supply Plan, Metropolitan Council Report to the Legislature, dated February 1, 1990. Publication Number 590-90-035.

USGS Groundwater study concerning groundwater connections to the Mississippi River is underway now.

APPENDIX A

CORRESPONDENCE

LETTER RECEIVED (cont'd)

Correspondence from	Date	Subject	Copy Included
Native American Interests			
U.S. Department of the Interior Bureau of Indian Affairs Minnesota Agency Robert T. Aitken	June 30, 1988	Recommendation: No deviation from the conservation plan	No
Mille Lacs Band Chippewa Indians Executive Branch of Tribal Gov Don Wedll	July 1, 1988	Opposition to drawdown of Sandy. Requested consultation before decision	No
Finn and Mattson Attorneys at Law	July 7, 1988	Prepared to litigate rights of Leech Lake Band	No
Leech Lake RBC Member James Michaud	July 27, 1988	Position: Vehemently opposes the release of tribal waters	No
The Minnesota Chippewa Tribe Darell Wadena	July 29, 1988	Chippewa Tribe support for Leech and Mille Lacs Reservations	No
Mille Lacs Band of Chippewa Indians Executive Branch of Tribal Gov Arthur Gahbow	July 29, 1988	Winter's Water Rights Doctrine	No
U.S. Department of the Interior Office of the Secretary C. Ray Smith	July 29, 1988	Discussion of Federal Indian Trust relationship	Yes

LETTER RECEIVED (cont'd)

Correspondence from	Date	Subject	Copy Included
U.S. Department of the Interior BIA Minnesota Agency Roger T. Aitken	August 1, 1988	No change in position	No
Leech Lake RBC Division of Resource Mgmt Joe Shepard	August 1, 1988	Data showing effects of lake levels on wild rice resources	Yes
State & Regional Government			
Governor's Office	July 28, 1988	Request with rationale for releases from headwaters lakes	Yes
Minnesota Pollution Control Agency	July 22 & August 30, 1988	Drought effects on waste administration	Yes
Metropolitan Council	July 27, 1990	Comments on & support for draft low flow review report	Yes
MDNR	Sept 26, 1990	Comments on draft report	Yes
State Senator Bob Decker		Need a stepped, trigger coordination system to provide more productive discussions earlier in event	Yes

LETTER RECEIVED (cont'd)

Correspondence from	Date	Subject	Copy Included
<u>Local Governments, Chambers of Commerce and Recreational Interests</u>			
Cass County Auditor Sharon Anderson	June 29, 1988	Resolution: Coordinated plan for water quantity during droughts; e.g., county involvement	No
Chamber of Commerce Grand Rapids Area Sandy Layman	July 5, 1988	Economic and environmental impacts on northern Minnesota	No
Chamber of Commerce Leech Lake Area D. Nevin Campbell	July 5, 1988	Release effects on area economic base	No
Congress of Minnesota Resorts Chick Knight	July 5, 1988	Drawdown effects on economy of northern Minnesota	No
Cass Lake Area Civic and Commerce Association Karol Savage	July 5, 1988	Economic and environmental effects drawdown	No
County Auditor Crow Wing County Roy A. Luukkonen	July 7, 1988	County Board Resolution Requests criteria and long-range plans prior to reducing levels	No

LETTER RECEIVED (cont'd)

Correspondence from	Date	Subject	Copy Included
Gull Lake Area Property Owners Association	July 18, 1988	Drawdown effects on Gull Lake Chain	No
Mississippi Headwaters Board Molly MacGregor	July 26, 1988	Request to serve as information coordination agency. Passed resolution opposing additional releases unless metro area conserves	Yes

Envelope pos. [illegible]

United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

Colonel Roger Baldwin
Department of the Army
St. Paul District Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, MN 55151-1479

Dear Colonel Baldwin:

It is our understanding that the governor of Minnesota requested that your District release water from Lake Winnibigoshish in order to alleviate water supply problems in the Minneapolis metropolitan area. Further, we were advised on July 28, that you had not made a decision on the request and that you are currently examining federal drawdown options in consultation with the Leech Lake and Mille Lacs Bands of Chippewa Indians and local Bureau of Indian Affairs officials. We urge that you continue to move cautiously in your deliberations.

In view of your forthright acknowledgement of the Corps' responsibility to protect Indian trust resources from risk of loss, we are optimistic about the possibility that you will find a workable solution which is consistent with the Indian trust responsibility and which is responsive to the public interest that may be affected by the Corps' general statutory authority to act.

The decision which you will soon be making should, in our view, involve consideration of several important issues. First, is there actually an emergency situation requiring a drawdown? Second, if it can be said that there is an emergency, what is the scope of that emergency and what are the minimum water resources required to respond to the needs of public health and safety? Third, who in the region can contribute to the solution in terms of actual water? Fourth, what water monitoring procedures must be implemented by the co-managers prior to drawdown implementation, particularly with respect to protection of Indian trust resources? Fifth, what water management decisions can be made now and/or in the future by federal, state and local interests to guard against the reoccurrence of this problem.

As our third point suggests, it must be considered whether State has other means available to ease the water shortages of the kind now being experienced by the Minneapolis metropolitan area. To the extent that these means exist they should be used to resolve the water shortage before water is drawn from sources that are necessary to the maintenance of the Indian trust resources. Furthermore, if the federal reservoirs in the region are to be used for drought relief, drawdowns should be coordinated at a minimum to avoid or mitigate impacts on the reservation environment.

In closing, we wish to request that, in the exercise of your authority in this matter, you include this office in the exchange of any information pertinent prior to the making of your final decision.

Sincerely,

C. Ray Smith

Deputy ~~to~~ the Assistant Secretary - Indian Affairs (Trust and Economic Development)

EMERGENCY WATER WITHDRAWALS FROM THE MISSISSIPPI HEADWATERS LAKES AND THEIR EFFECTS UPON LEECH LAKE BAND OF CHIPPEWA INDIANS

PREPARED BY:
DIVISION OF RESOURCES MANAGEMENT
LEECH LAKE RESERVATION BUSINESS COMMITTEE
JOSEPH B. DAY, DIRECTOR

INTRODUCTION

The Leech Lake Indian Reservation, located in north central Minnesota, was reserved by the Leech Lake Band of Chippewa by treaty with the U.S. Government in 1855 and continues under modifying provisions of subsequent treaties and executive orders. The Reservation is comprised of approximately 588,684 acres of forests, wetlands and natural lakes and flowages. The northern most reaches of the Mississippi River traverse the Reservation from west to east through a series of large, scenic lakes. The southern area of the Reservation is dominated by Leech Lake, a tributary of the Mississippi River via the Leech Lake River. Leech Lake and Lake Winnibigoshish lie within the Leech Lake Reservation and are the first two of the six controlled lakes that make up the Mississippi River Headwaters Lakes System. Of the six Mississippi River Headwaters Lakes, Leech Lake and Lake Winnibigoshish contain approximately 75% of the system's capacity.

HISTORICAL PERSPECTIVE

The six water control dams on lakes in the Mississippi Headwaters area were constructed by the U.S. Army Corps of Engineers between 1881 and 1913. The original stated purpose of this system of dams was to "improve navigation and provide some minor benefits to logging." What should also be recognized is that Congressional authorization in 1880 for construction of the Mississippi Headwaters Reservoir System was promoted by powerful Minneapolis water power and milling interests that garnered the greatest benefits from their construction. The United States made no effort at the time to consult with the Leech Lake Band, whose lands and natural resources they were proposing to destroy in order to assure the City of Minneapolis' future as a great center of commerce and industry. After construction had begun on the Headwaters dams, Congress did direct the Secretary of the Interior to estimate any damages to the property of "friendly Indians" in the construction of the dams. It should be noted at this point that settlement of the damages case filed by the Minnesota Chippewa Tribe against the U.S. Government was settled in 1984 for approximately $3,300,000.00, over one hundred years after the fact.

The history of Headwaters Lakes operations also depicts situations wherein tribal rights and interests have been subjugated to the interests of more powerful groups. The same Minneapolis manufacturing and water power interests that pushed for the Headwaters dams to be constructed also had a great deal of influence on their operation for many of the early years. Leech Lake and Lake Winnibigoshish have also been operated to prevent flooding damages to predominantly agricultural lands in the Aitkin area during high flow years causing severe damages to tribal wild rice crops. These damages went unacknowledged by the Corps.

In the 1930's the Corps of Engineers constructed a series of locks and dams at and below Minneapolis to provide a 9-foot navigation channel. This project reduced low-flow water needs for navigation to 350 CFS, virtually eliminating any utility of the Mississippi Headwaters in maintaining river navigation downstream from Minneapolis. While navigation requirements had been effectively met, a number of upstream and downstream interests have remained concerned about the operation of the Headwaters Lakes. At the request of some of these interests, Congress requested a study of the Headwaters Lakes in 1945 for the purpose of recommending modifications in operating plans to enhance flood control, recreation, fish and wildlife and other purposes.

This study was initiated in 1945 but not completed. In 1976, another low-flow year, the study was reactivated and completed in 1982. The Leech Lake Band of Chippewa Indians participated in the study during these years in order to provide the Corps of Engineers with an understanding of their unique cultural, legal, political and economic status and the Corps' abilities to affect their interests via Headwaters Lakes operations. The result of the Band's participation in the Headwaters Study was the refinement of operating plans for Leech Lake and Lake Winnibigoshish primarily to enhance wild rice production as well as fish and wildlife habitat. It is interesting to note that prior to tribal participation in the Headwaters study the St. Paul District was basically unaware of their responsibilities in fulfilling the U.S. Government's trust relationship to American Indian tribes. The District, however, must be commended for their recent acceptance and implementation of actions to correct this oversight.

The foregoing historical account of the development of the Mississippi Headwaters and its effect upon the Leech Lake Band of Chippewas is intended to provide some insight into the vehement opposition of the Band to the proposed use of Reservation waters in 1988 to supplement Twin Cities flows. The band has already suffered grievous losses of their land and natural resource base to accommodate Minnesota's growth over the past one-hundred years. Per capita income of Indians residing on the Leech Lake Reservation is $2,368.00, well below the national poverty level. Unemployment, alcoholism, illiteracy and other social blights are pervasive problems among Indian populations today. The problems of the Chippewa people are difficult to understand unless one is cognizant of the history of disenfranchisement, discrimination and disrespect imposed upon the Bands during the past 120 years because someone else coveted our lands and resources. We have been made refugees in our own land.

The people of the Leech Lake Reservation do not wish for hardship to befall other people and pray along with others that rain will come and relieve those who suffer from this drought. However, we are justifiably indignant when the Leech Lake Band is once again chosen to sacrifice for the relief of those who have the resources available to provide for their own relief but have not done so. Our water is wanted to maintain quality in the Mississippi River primarily below the Twin Cities.

The Minnesota River would be providing that relief if land use practices within that basin were rational. Instead its quality is diminished to the point where it is worse than the effluent discharged from the Pigs Eye wastewater treatment plant. Water we need is requested to guarantee the Minneapolis public water supply system remains functional. Periods of low flows in the Mississippi have been recognized as a problem since the city was founded and yet, despite knowledge and warnings has yet to tap their rich groundwater resources to provide their own relief. Is it truly easier to impose upon us? Water we need is requested so that electric power production will remain optimal. Is it truly easier to impose upon us rather than experience a temporary increase in electricity rates or, at the worst, conserve on its use? Will a decision to provide some relief by allocating Lake Winnibigoshish water to the Twin Cities on an "emergency" basis solve these water problems? We think not.

Wild Rice Resources

Leech Lake Reservation Division of Resources Management staff have identified a total of 35 indivi:al rice beds on Lake Winnibigoshish and connecting flowages affected :. the operation of Winnie Dam. Rice bed acreages were calculated and the quality of the stands rated. Total wild rice acreage is estimated at 2,752.90 acres. Stand quality ratings relate to estimated harvest values as follows:

Rating	Acres	Harvest Production/acre	% of stands in rating category	Estimated Harvest
Excellent	1,410.25	300 lbs.	51%	423,075. lbs.
Good	1,303.50	145 lbs.	48%	228,113. lbs.
Poor	39.15	50 lbs.	1%	1,958. lbs.
		1988 average:		
TOTAL	2,752.9	237.26 lbs./acre	100%	653,146. lbs.

When compared to other year's production levels, 1988 represents a bumper crop year for wild rice production on the Leech Lake Reservation. In poor years harvest rates have been below 50 lbs./acre. Average annual harvest production is approximately 110 lbs. per acre. A bumper crop such as there is in 1988 has historically occurred on the average of once every five years. In this context the 1988 standing crop represents 44% of production within a five year cycle.

The value of the wild rice crops is presently low in comparison with market value over the past twenty years. Prices paid have varied from approximately $4.00 (1988 dollars) per pound for green rice in 1972 to $0.65 (1988 dollars) in 1987. Processing of wild rice reduces its weight by 50 to 60 percent. The market price of processed wild rice was $4.50/lb. in 1987. Individual harvesters have generally adjusted to market conditions by selling more wild rice on the market when prices are high and

retaining it for subsistence use when prices are low. Over the past 20 years Band members have marketed about 70% of the crop and retained 30% for their own consumption. While not scientifically verified, wild rice pickers estimate they harvest about one third of total lake production, the remainder being consumed by wildlife or naturally reseeding the bed.

Wild rice is an aquatic grass and an annual plant, growing from seed each season. As such, plant stress can have a profound effect on production. Wild rice grows best in one to two feet of water. The plant will grow in depths outside of this range but produce less seed. The major effect of a drawdown, as is being contemplated, on wild rice plants in the reproductive stage is on the physical stability of the plants. As more of the supporting stem becomes emergent, the likelihood of wind and water action or plant weight lodging the plants increases. No studies are known to exist that quantify this problem, which is weather dependent in any case. Lodging may or may not kill the plant or affect seed formation. In any event, lodging causes severe problems with respect to harvesting.

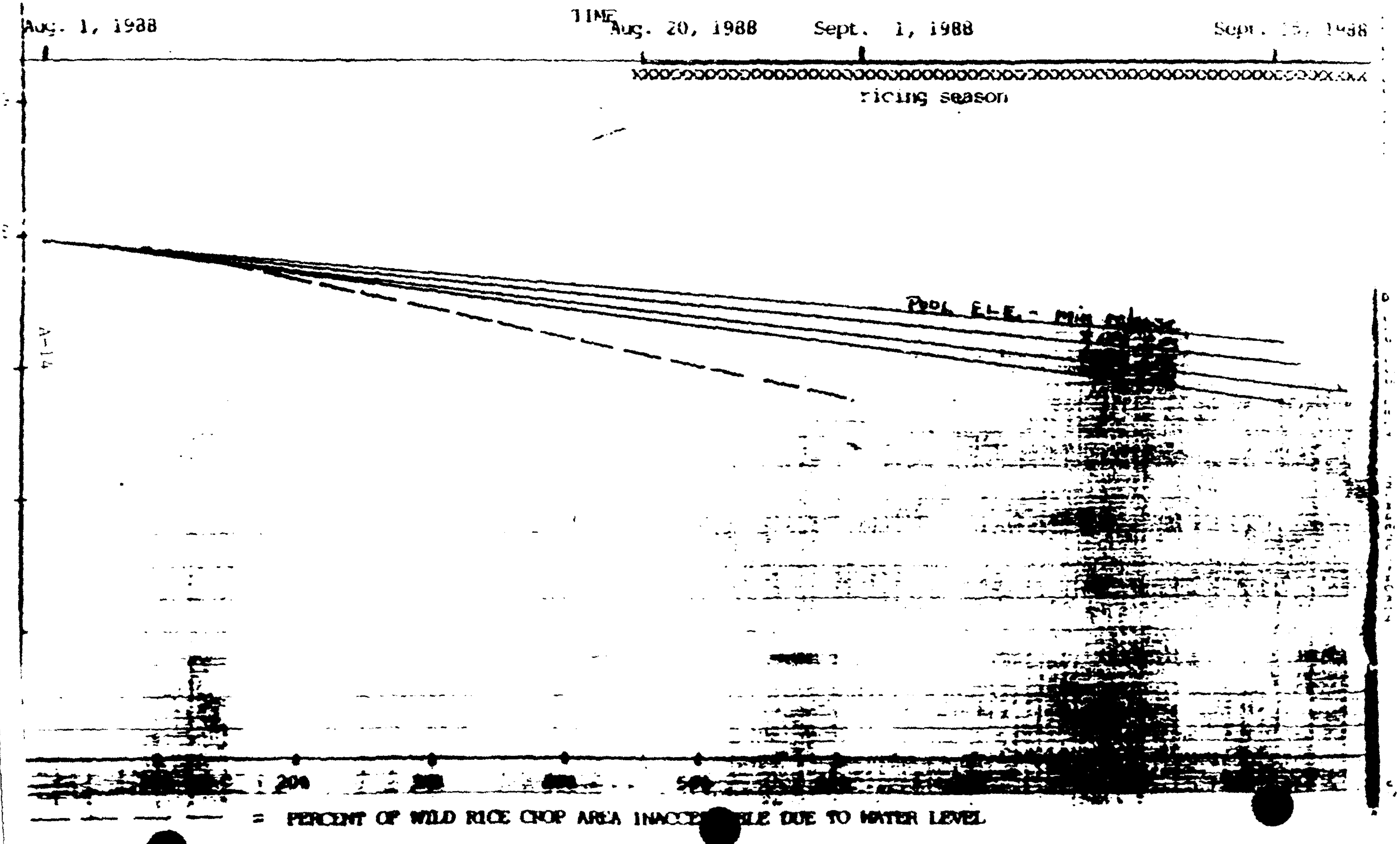
Probably the most significant effect the proposed draw-down of Lake Winnibigoshish will have on the wild rice crop is that of sufficient water depth in the beds to harvest the crop. Wild rice is traditionally harvested by a team of two individuals in a canoe. One individual stands in either the front or rear of the canoe and uses a long slender pole to propel the canoe through the bed. The other individual sits in the middle and harvests the wild rice using a pair of flails or knockers to knock ripe seeds off the plants. The wild rice seeds do not ripen at the same time and thus harvesting is performed over the same bed many times over a harvesting season which generally lasts from mid-August into October. The majority of wild rice harvested from Lake Winnie and its flowages occurs between August 20th and September 15th.

In order to estimate the losses of harvestable wild rice due to inaccessibility, several of the wild rice beds on Winnie were surveyed on July 20, 1988 to determine present water depth. A graph was produced to roughly estimate percentage of crop acreage that would be inaccessible to harvest versus lake elevation. As water levels will decline over time as the harvest is in progress and the dates of harvest are dependent on

weather conditions and other factors which cannot be determined, a probable range of losses must be determined. Continuing minimum releases of 100 CFS at Winnie Dam result in an estimated loss of 22% wild rice acreage at the beginning of the season which increases to a 42% loss in harvestable area by September 15th. With an additional 300 CFS released, areal losses of harvestable wild rice at the beginning of the season are estimated at 42% with an increase to 61% by September 15th. Losses of wild rice to lodging would most likely increase at an increasing rate as the lake level drops, although it is impossible to predict how much. Approximately 5% of the crop was inaccessible on July 29, 1988.

PERCENT OF WILD ... CROP INACCESSABLE TO HARVEST
... LAKE WINNIBIGOSHISH 1988

RAIN FREE PERIOD



CONCLUSIONS AND RECOMMENDATIONS OF THE DIVISION OF RESOURCES MANAGEMENT, LEECH LAKE RESERVATION BUSINESS COMMITTEE

After consultation with the St. Paul District Engineer and his staff on the proposed drawdown of Mississippi Headwaters Lakes to augment flows in the Twin Cities, the Leech Lake Reservation Business Committee understands that, due to its present low stage basin characteristics and the large amount of wild rice production (approx. 4,300 acres), Leech Lake is effectively not being considered by the District Engineer for further drawdowns to augment downstream flows. If this is not the case, the Leech Lake RBC should be contacted immediately and informed otherwise.

As the Governor of the State of Minnesota has requested that the District Engineer order an emergency release of an additional 300 CFS from the Mississippi Headwaters and specifically recommended the entire 300 CFS be taken from Winnibigoshish, the Leech Lake Reservation Business Committee wishes at this time to reaffirm our complete opposition to the release of Reservation waters for the purpose of augmenting river flows for the purposes intended. Specifically; the assimilation of wastewater effluent to maintain water quality below the Pigs Eye wastewater treatment plant; to ensure optimum power production from steam electric plants utilizing the Mississippi River as a source of cooling water. After careful consideration of the facts of the matter, we honestly cannot say that we believe that a true state of emergency exists with respect to low river flows in the Twin Cities area.

It appears to the RBC that these problems have solutions other than Headwaters Lakes withdrawals with the exception of maintaining water quality below the Cities. It also appears to the RBC that a release of an additional 300 CFS would not do much to improve said poor water quality conditions. The taking of water reserved for in-stream uses in one place to provide for in-stream uses in another would be difficult at best to justify as wise, especially when the relative importance of in-stream uses in this particular case are examined.

The Leech Lake RBC is also under the impression that the first navigation lock in Minneapolis could be closed to ensure a high enough stage in the Mississippi to cover the water supply intake serving Minneapolis and the suburbs. While this action would most certainly worsen water quality conditions downstream and is likely to be somewhat inconvenient with respect to navigation, it does provide a local solution to a local problem. The RBC trusts that a hard look at former low flow years with an eye towards determine groundwater contributions to river flow to ascertain to what extent the Minneapolis public water supply is threatened and thus whether a state of emergency truly exists.

With respect to steam electric water requirements, Minnesota Power Company officials publicly stated that they could continue to provide their customers with power even if they were forced to shut down their plants taking water from the Mississippi River. A complete shutdown does not appear very likely though as these plants are designed to continue in operation at lower power outputs by recycling cooling water. Inconvenient yes, but not an emergency.

With respect to potential damages to the Reservation's natural resources we have estimated that with only minimum releases from Winnie Dam and no appreciable precipitation through the harvest season, a 22 to 42 percent loss of harvestable acreage will occur on Winnie and connecting flowages due to insufficient water depth for harvesting operations. If an additional 300CFS were released from Winnie Dam, the loss of harvestable acreage would increase to approximately 42% at the beginning of the ricing season to 61% at the end. Our estimates of crop loss in the worst case, supplemental drawdown option being considered by the District Engineer is over 20% of the crop, as lodging of stands would also produce an unquantifiable loss. With a wholesale market value of $4.50 per processed pound, the worst case scenario is estimated to represent a potential economic loss of $293,915.00 to harvesters and processors of wild rice.

Significant impacts on fisheries are not anticipated from the proposed drawdown, however there may be some impacts occurring if normal operation levels are not regained by late April of 1989. Low water levels at this time could greatly impair spawning success within the lakes fisheries.

Wildlife habitat is also a concern expressed by the Reservation's people, however no assessment of potential impacts has been completed at this time. Of specific concern are fur bearing mammals which our trappers rely upon and dwindling waterfowl populations. Any efforts on the District's part to assess potential impacts to wildlife resources would help greatly to make up for our shortcomings in this area.

As to this issue bearing upon the special legal status of the Leech Lake Band, we have little to add to our previous correspondence submitted within the framework of the Headwaters Study. At the RBC's meeting with the District Engineer held on July 28, 1988 the RBC was reassured that the District Engineer understands the nature and obligations of the Federal trust responsibilities that he must uphold when making a decision regarding the Governor's request. We do, however feel that there is a need to state at this time that the Reservation Business Committee views any diminishment of the Leech Lake Band's trust estate as a result of the District Engineer's decision and actions on this matter as a taking of Band property for public purposes and therefore subject to the Band's receiving just compensation for any and all losses as well as any taking of trust property being performed in a manner consistent with existing law regarding the taking of tribal trust property.

It should also be known that the Leech Lake Reservation Business Committee does not view the present situation as a water rights issue, but as an issue of wise and present water resource management. Water is the first limiting factor in the growth and development of human settlement. Respectful care and stewardship of our nation's precious lands, waters and all living things, both now and in the future, is foremost in our minds and most importantly in our hearts. Perhaps some will say we are selfish to object to the Governor's request. But then others may think long and hard before permitting another wetland to be filled in order to "improve" the land's value. And perhaps others will place more value on the water they use and find it offensive to waste it. And perhaps someone living one hundred years from now will come to Minnesota and find clean lakes and streams, marshes teeming with life and chosen ways of life preserved by people with the foresight to wisely manage and protect the resources that sustain them.

RUDY PERPICH
GOVERNOR

STATE OF MINNESOTA

OFFICE OF THE GOVERNOR

ST. PAUL 55155

July 28, 1988

Colonel Roger L. Baldwin
District Engineer, St. Paul District
U.S. Army Corps of Engineers
1421 U.S. Post Office and Custom House
St. Paul, Minnesota 55101

Dear Colonel Baldwin:

On behalf of the people of the State of Minnesota I hereby request the release of water from the headwaters reservoirs to augment flow in the Mississippi River.

This action is being requested due to the continued nature of the 1987-88 drought and is in accordance with the recommendations of the State Drought Task Force.

Specifically, our initial recommendation is for the release of an additional 300 cubic feet per second (cfs) from Lake Winnibigoshish Reservoir to provide base flows adequate to:

1) minimize water quality problems and protect in-stream needs;
2) insure a reliable supply of water for domestic demand; and
3) provide reasonable levels of power production.

Specific documentation of this request is attached. Clarification and additional information is available through the Department of Natural Resources, Division of Waters Director Ronald M. Nargang.

Sincerely,

RUDY PERPICH
Governor

I. Existing Situation

The 1987-88 drought is having a profound impact on streamflow statewide. Palmer Drought Index ratings indicate more severe drought conditions in portions of the state than those experienced in 1934. Flows in the Mississippi River have fallen to seriously low levels and computer projections from the River Forecast Center indicate that we must anticipate and plan for historic low flows to occur during August 1988. Although weather patterns seem to be returning to normal we see not indication of rains sufficient to alleviate general drought conditions or support base flow in the Mississippi River.

What the projec

II. Impacts of the Low Mississippi River Flow

A. Water Quality

What are the specific [illegible]

Water quality impacts are being felt along all of the Mississippi River. Along certain reaches the water is becoming more stagnant, temperature is increasing, dissolved oxygen is decreasing, and productive substrate is being exposed. The demands on the river for waste assimilation remains relatively constant and other point sources continue to contribute to the demand on the river system. Without substantial additional flow, conditions will continue to deteriorate.

With additional flows it will deteriorate.

B. Water Supply

The following Cities are dependent on the Mississippi for a major portion of their water supply:

St. Cloud	95%	(___ cfs)
Minneapolis	100%	___
St. Paul	60%	___

Current projections of flow indicate serious problems meeting the demand, even though total demand is reduced by implementation of conservation measures.

This is fact. 30 500 CFS to SUPPORT H_2O SUPPLY TO T.C.

C. Power Production

Reduced water flow limits the capacity of power generation along the river for both hydropower and nuclear power generation. Most critical is the maintenance of a reasonable level of generation from the nuclear facility at Monticello

SEE NSP LETTER TO OBERSTAR / NOT SUPPORTED.

lm. 1503

DEPARTMENT MN POLLUTION CONTROL AGENCY

STATE OF MINNESOTA

Office Memorandum

DATE July 22, 1988

TO Stan Kumpula, Assistant Chief of Engineering
U.S. Army Corps of Engineer
St. Paul District Office

FROM Timothy K. Scherkenbach
Director
Division of Water Quality

Tim S.

PHONE 296-7202

SUBJECT : SUMMARY OF WASTE ADMINISTRATION IMPACTS DUE TO DROUGHT SITUATION ON MISSISSIPPI RIVER

This is in response to your request for information regarding potential impacts on the Mississippi River due to drought conditions. The information we have available is based upon data that was recently collected during a low flow survey. Any future impacts under flow conditions of even lesser volumes are speculative due to our inability to model and predict impacts at flow levels less than 7Q10 conditions.

With respect to dissolved oxygen in the Mississippi River downstream from the Metro Area, declining river flows during the current drought have reduced the river's total capacity to assimilate wastewater effluents from the Metro Plant located at river mile UM-835. Less water is available for dilution. A zone of depressed dissolved oxygen levels occurs downstream from the plant, reaching minimum concentrations approximately five miles downstream at river mile UM-830. Thereafter, dissolved oxygen begins to recover, aided significantly by the photosynthetic production of oxygen by algae in the river.

An intensive survey conducted jointly by the MWCC and the MPCA between June 17 and July 1, 1988, documented water quality conditions of the Mississippi River under summer low flow conditions. During this period, river flows at St. Paul were in the 1500-1700 cubic feet per second (cfs) range, which represents a summer low flow having a probability of occurrence once every ten years. Under these low flow conditions, wastewater treatment plants are designed to maintain water quality standards 50% of the time. At river flows below the design flow, one would expect a reduction in compliance.

During the first part of the river survey, minimum dissolved oxygen concentrations measured at sampling stations near river mile UM-832.5 and UM-831 were typically in the 4.0 to 5.0 mg/l range at mid-depth. Recovery to the water quality standard of 5.0 mg/l occurred by river mile UM-826 near the head of Spring Lake. Algal productivity in the Spring Lake reach extending down to the dam at Hastings elevated dissolved oxygen to supersaturated concentrations.

During the last week of the survey, dissolved oxygen concentrations at the sag point were maintained above 5.0 mg/l, presumably from increased algal activity. A complete analysis of water quality conditions during this period will be conducted later this summer when water chemistry analysis and biological data become available.

At the time of the June survey, the effluent from the Metro Plant represented about 1/5 of the total flow in the river downstream from the Metro area. If Mississippi River flows continued to decline into the 700-800 cfs range at Anoka, the Metro Plant flow would represent 1/4 of the total downstream flow. Judging from the river's response to loadings during the June survey when minimum dissolved oxygen concentrations were measured in the 4.0 to 5.0 mg/l range, one could reasonably expect minimum concentrations in the 3.0 to 4.0 mg/l range under the more severe flow case. An approximate 10 river mile zone below the Metro Plant discharge could be subject to depressed dissolved oxygen due to algal productivity. Meteorological factors such as temperature, solar radiation, and wind will ultimately play a major role in determining the dissolved oxygen budget and the frequency and duration of water quality problems under severe low flow conditions.

Throughout this entire drought period the Metro Plant has consistently performed better than the conditions of its NPDES permit require. It is removing organic material and other pollutants essentially at the limits of its technological capabilities. Current BOD_5 levels in the discharge are averaging between 7 and 8 mg/l. Given its past history, we anticipate that the plant will continue to perform at maximum efficiency in the future. In addition, the plant is pumping its treated effluent over the flood dikes which raises the dissolved oxygen to 7 mg/l or above at the point of discharge into the river.

Concerning additional alternatives for lowering waste assimilation impacts on the river, we don't know if there are really any cost-effective options available. Mechanical aeration was discussed; however, concensus is that the benefits derived vs. the cost of implementation and operation wouldn't prove to be workable. Consequently, we didn't attempt to do a detailed analysis of that option. The only other possibility that we came up with was the potential for reaeration at the locks and dams. This alternative, if feasible, might provide some positive impacts below the Ford Dam where the Minnesota River is coming in with dissolved oxygen levels in the 3.5 mg/l range. Perhaps the Corps of Engineers could explore the possibility of utilizing the dams, particularly the Ford Dam, to provide some reaeration to the river.

I hope this information satisfies your needs and helps in formulating your final position paper. Should you have any additional questions, please don't hesitate to contact me.

PM/jms
cc: Ron Nargang - MDNR

DEPARTMENT MINNESOTA POLLUTION CONTROL AGENCY

SF 00006-C

STATE OF MINNESOTA

Office Memorandum

DATE : August 30, 1988

TO : Stan Kumpola, Assistant Chief of Engineering
U.S. Army Corps of Engineers
St. Paul District Office

FROM : Timothy K. Scherkenbach
Director
Division of Water Quality

PHONE : 296-7202

SUBJECT : SUMMARY OF WASTE ASSIMULATION IMPACTS DUE TO DROUGHT SITUATION ON MISSISSIPPI RIVER

This is a follow-up to my July 22, 1988, memo to you concerning the above-referenced subject. There was a typographical omission in that memo which significantly changed the meaning and intent of a point I was trying to make. This memo will clarify what was intended.

On page 2 paragraph 2 the original memo reads "An approximate 10 river mile zone below the Metro Plant discharge could be subject to depressed dissolved oxygen due to algal productivity. Meteorological factors such as temperature, solar radiation and wind will ultimately play a major role in determing the dissolved oxygen budget and the frequency and duration of water quality problems under severe low flow conditions." The memo should read "An approximate 10 river mile zone below the Metro Plant discharge could be subject to depressed dissolved oxygen. However, because dissolved oxygen concentrations are highly sensitive to algal productivity, meteorological factors such as temperature, wind and solar radiation will play a major role in determining the dissolved oxygen budgets and the frequency and duration of water quality problems under severe low flow conditions. (emphasis added)."

I hope this memo clarifies the Minnesota Pollution Control Agency staff's assessment of the impacts on the Mississippi River caused by the drought. The mistake in my original memo made it appear as though algal productivity was depressing the dissolved oxygen levels and that certainly is not the case. Please do not hesitate to contact me if you have any questions.

TKS:alb

cc: Ron Nargang - MDNR

METROPOLITAN COUNCIL Mears Park Centre, 230 East Fifth Street, St. Paul, MN 55101 612 291-6359

July 27, 1990

Col. Roger L. Baldwin, District Engineer
St. Paul District, U.S. Army Corps of Engineers
1421 U.S. Post Office and Custom House
St. Paul, Mn. 55101-9808

ATTN: Herb Nelson

RE: Mississippi River Headwaters Lakes in Minnesota
Low Flow Review

Dear Col. Baldwin:

Thank you for sending us the draft plan referenced above. The Metropolitan Council's Natural Resources staff reviewed the plan relative to our on-going water supply planning efforts referenced in the plan. Our comments are not extensive, since Council staff has reviewed a similar, previous document. We believe that the plan clearly portrays the Corps' responsibilities relative to the Headwaters project lakes. We are very pleased that the plan acknowledges the possibility of extreme water supply conditions, and provides for a supplemental release mechanism to assure public health during such an event. This is a critical element in assuring back-up water supply for the Metropolitan Area under near-catastrophic conditions. We support the Corps' finding that MDNR must ensure appropriate and permitted withdrawals from the river before any additional flows are authorized by the Corps. Such an approach is the heart of the Council's water supply planning efforts. The "critical" flow figure of 554 cfs is consistent with the Council's similar definition in it's short-term water supply plan (discussed later in these comments).

We are hopeful that the establishment of an in-house drought management team will allow the Corps, as one of many important players, to respond to the public's need to know information during a drought. The Council will cooperate in any manner we can to assist the Corps' team or to provide them with information.

The Council supports the plan recommendation to coordinate the efforts of all mainstem dam operators, in conjunction with the MDNR. As you have shown in the plan, the uncoordinated actions of individual dam operators can have a dramatic impact on the flow of even the Mississippi River. Controlling this impact is essential to our efforts to assure an adequate flow of water to the region during a shortage.

As you are aware, the Council prepared a short-term water supply plan and presented it to the Minnesota Legislature in February 1990. This plan contained a stepped response matrix that is an adaptation of a similar matrix developed by the MDNR in anticipation of a 1989 drought. Prior to submitting this plan to the legislature, the Council received commitments from all parties in the matrix that they would perform as outlined. Also, the 1990 legislature required the MDNR to consider the matrix in its preparation of a statewide drought emergency plan. The Council/MDNR matrix is certainly consistent with the "Agency Drought Coordination Matrix" contained in the Corps' plan; however, the two matrices address slightly different parties from slightly different angles. Reference to the short-term plan matrix in the Corps' plan would make readers aware that a separate document exists outlining a regional strategy to achieve the same end as the Corps.

As noted in the plan text, the Council is currently working on a long-term water supply plan. The text (page 46) reports the old due-date of July 1, 1990. The 1990 legislature revised the plan due-date to February 1, 1992.

For informational purposes, the Corps should be aware that the Council has prepared, with some assistance from the Corps, a rough approximation of what it would take to supplement Mississippi River flows from two abandoned Mesabi Iron Range pits. The possibility of accomplishing this appears to be technically quite feasible. Several potential interested Mississippi River users have been approached to get a measure of their interest. Although we await word from some of the parties, it appears that a great deal of cautious optimism exists about the use of this largely untapped water supply. The ultimate cost and renewability of the supply are largely undefined, but interest in pursuing the source is high. We will certainly involve the Corps in any detailed discussions that develop.

The list presented in Figure 3 of Appendix D is not current. In addition to several personnel changes in the list, the Council is not listed although it has been a member of this group for quite some time.

Table E-2 was also rendered obsolete by the low flows of 1988. Although a full, post-1988 low flow study has not been completed, as stated in the plan, it should be made more clear that the figures presented will drop when 1988 is factored in. The plan later (page H-2) reflects the lowered 7Q10 flow at St. Paul; perhaps some reference to the impact of 1988 and to the later discussion would "update" Table E-2 to current.

Finally, I would like to thank the Corps for your assistance in obtaining the IWR-MAIN water use model and beginning its development in the Metropolitan Area. As you might be aware from your discussions with Stan Kummer, the model has not worked well with our particular mix of mid-continental climate and numerous municipal suppliers. I would like to request the Corps' IWR, as part of its support for this model, work with the St. Paul District in calibrating the model for this part of the country. We have found that the PC version of the model has not been calibrated for the mid-continent and that many of the assumptions that work on either coast do not work here. Since this model is an invaluable part of our water planning effort, I urge the Corps to adjust it so that the outputs that we rely so much upon are accurate. Any assistance that we can offer in the areas of providing data or interpreting results/needs, we will happily provide.

In summary, we are extremely pleased that the Corps has reevaluated the operation of the Headwaters Lakes project and has found that there may be occasions when additional releases are warranted. Please let us know if there is any way in which we can be of assistance in your future deliberations. Again, any assistance you could obtain from IWR in the regional calibration of the MAIN model would be greatly appreciated. We look forward to continued cooperation as we prepare the long-term water supply plan for the region over the next year and one-half.

Sincerely,

Steve Keefe

Steve Keefe
Chair

cc: Herb Nelson, Corps of Engineers
Stan Kummer, Corps of Engineers

STATE OF MINNESOTA
DEPARTMENT OF NATURAL RESOURCES
500 LAFAYETTE ROAD, ST. PAUL, MINNESOTA 55155-4037

OFFICE OF THE COMMISSIONER

DNR INFORMATION
(612) 296-6157

Celebrate MINNESOTA 1990

September 26, 1990

Colonel Roger L. Baldwin
District Engineer, St. Paul District
Corps of Engineers
1421 U.S. Post Office and Custom House
St. Paul, Minnesota 55101-1479

Dear Colonel Baldwin:

Thank you for the opportunity to respond to the "Draft" for your Headwaters Lakes Low Flow Review (June, 1990), and for staff to respond to questions at your public meeting sponsored by the Mississippi River Headwaters Board on July 18, 1990, in Walker, Minnesota.

Your staff are to be commended in their effort to alleviate many of our concerns relative to the earlier "Working Papers" document. Most important was the incorporation of "trigger" flows (in cfs) that correspond to the Conservation, Restriction and Emergency phases identified in the Agency Drought Coordination Matrix.

There seems to be, however, some confusion differentiating between the actions taken by the Corps based on the National Weather Service (NWS) flow predictions and actions taken by the Corps based on actual flows at Anoka. We concur with the description in the "Executive Summary" explanation that "The District's emergency actions will be triggered by the NWS 30-day prediction...." On page 48, paragraph 5, it is stated "Attainment of this level of Flow" (554 cfs) "in the matrix (Table 6) will trigger the consideration of alternative sources of water, including a supplemental release from the Headwaters Reservoir system." This statement seems to fit the Restriction Phase under State and Federal Actions in the matrix. Under Emergency Phase it is stated "implement emergency releases from reservoirs above low flow plan", when flows fall to the "trigger" of 554 cfs. Further clarification of this issue is desired.

There also continues to be a difference of opinion on the relative priority rankings for use of the project waters. I am aware of the meetings that have taken place between the Corps counsel and the Attorney General's Office which have helped to clarify positions. The obligations placed upon the District Engineer and the Secretary of the Army pertaining to Native American water rights is recognized. However, a simultaneous obligation and duty also exists to other members of the public

as termed "general public good" which includes all the many uses and values identified in the Low Flow Review.

I look forward to our continued close working relationship in all water resource-related issues.

Yours truly,

Joseph N. Alexander
Commissioner

c: Bill Clapp
Molly McGregor
Ron Nargang
Ken Reed

FROM DECKER'S DESK...

Notes from Sen. Bob Decker
151 State Office Building
St. Paul, MN 55155

Toll-Free Capitol Hotline: 1-800-451-5348

What were you doing two months ago? Yes, Minnesotans were in the middle of relentless, sweltering-hot weather; but I suggest that many in our northern lake region were "Hot" for another reason. Only two months ago, it seemed inevitable that Lake Winnie would be tapped to feed a feeble-flowing Mississippi River.

Now some of you might remember how "Hot" you were!

One can say,"Hindsight is 20-20;" but I felt all along the issue of the Mississippi drawdown was a proverbial political football. And the fact that it's an election year contributed to this hypersensitivity. It's a question with workable solutions, and shouldn't have been transformed into a grandstanding opportunity for attracting sensationalistic media coverage. Let me explain why.

As early as May, this region of the U.S. knew the drought could be a reality. State officials should have then been jockeying game plans and reassuring the public they were looking into precautions.

Instead, there was a wait-and-see attitude resulting in news stories which pitted the DNR (Dept.of Natural Resources), resort owners, and the local Chippewa band against a Governor who was depicted as precariously dealing with Twin City officials and a population of seemingly apathetic Twin Cities homeowners with lawn sprinklers.

Why couldn't there have been low-key discussions earlier in the running? Instead, we got play-by-plays on flaring tempers and heated words that were only cooled after the mighty river was blessed with some rain.

This fracas of North versus South, rural versus urban,and trying to figure out who's wearing the white hats and who wore black hats, only did a disservice to our area. After all,just as "Our water"

(Continued on Page 7)

FROM DECKER'S DESK...
(Continued from page 5)

flows down to the cities; the Twin Cities is a pipeline of livelihood up to our local economy via tourism and recreation dollars.

What's needed is a system of explicit,precautionary measures. And each measure would be triggered at the rate of worsening conditions.

While many Twin Citians were prudent water users during sprinkling bans, there should still be a "Phase system" for water use in the metro area. As a drought threatens and progresses, increasingly stricter water use limitations would go into effect(and begin earlier, too). Minneapolis must also develop better contingency plans. When the drought of 1976 brought the lowest water levels in state history, St. Paul, later drilled wells for auxiliary water. Minneapolis did not, and continues to rely upon the Mississippi.

In times of drought, the state Commerce Dept.should monitor local economies, and critical statistics should be immediately forwarded to the Governor's Office. The telephone can be an efficient method for tribal governments to give wild rice crop updates to state officials who are considering a drawdown. Likewise,resort owners would also appreciate regular acknowledgements from the state; rather than eleventh-hour, after-thought offers to dredge lake bottoms.

This summer's Mississippi drawdown proposal provided an opportunity for anyone to play a part in a media display of panic. But wouldn't it have been more productive if early negotiations were used to bypass potential controversies?

It's a question that should still be lingering even four months from now -- when, hopefully, a thick, long-overdue blanket of snow covers the state and will rejuvenate the Mississippi.

Mississippi Headwaters Board
Representing Clearwater, Hubbard, Beltrami, Cass, Itasca, Aitkin, Crow Wing and Morrison Counties
Cass County Courthouse, Walker, MN 56484 218-547-3300 Ext. 263

July 26, 1988

Governor Rudy Perpich
130 State Capitol
St. Paul, MN 55155

Dear Governor Perpich:

Following two public meetings in northern Minnesota, the Mississippi Headwaters Board has been asked to serve as a local body coordinating information regarding operations of the dams on the Headwaters lakes of Winnibigoshish, Leech, Pokegama, Sandy, Cross and Gull. The Mississippi Headwaters Board accepted this role, in part because the board has been coordinating meetings with the U.S. Army Corps of Engineers and other dam tenders on the Mississippi Headwaters since February 1987.

After considerable discussion, the Mississippi Headwaters Board passed the enclosed resolution opposing additional releases from the Headwaters dams unless conservation methods are effectively implemented in the Twin Cities area.

Furthermore, the members of the MHB have asked me to convey to you their deep concern that the 1,000 cubic feet per second at Anoka Mississippi River flow now being used as a triggering point for additional releases is too high. The board members feel that too little is really known about the needed water levels in the river, both in the metropolitan area and in northern part of the state.

For that reason, we respectfully request that you consider expanding your current support for relieving short term problems due to the draw down with additional support for long range planning for water quantity and quality in the state. We don't know the long term effects of additional releases, and since this problem is bound to recur in the future, if not next year, we believe the time is right to initiate long range planning to better understand the state's precious water resources. The Mississippi Headwaters Board, through its dam tenders group, has been working towards an update of the U.S. Army Corps of Engineers operating plan in the Headwaters area and has requested additional support from the state for this effort. It has become obvious that this is a state-wide problem that needs state-wide support to find solutions.

Sincerely yours,

Molly MacGregor,
Administrator

cc: Mississippi Headwaters Board
Ron Nargang
Colonel Roger Baldwin

Mississippi Headwaters Board
Representing Clearwater, Hubbard, Beltrami, Cass, Itasca, Aitkin, Crow Wing and Morrison Count
Cass County Courthouse, Walker, MN 56484 218-547-3300 Ext. 263

RESOLUTION OF THE MISSISSIPPI HEADWATERS BOARD

Drawdown Of Headwaters Lakes Reservoirs

WHEREAS, the stated purpose of the Mississippi Headwaters Board is to formulate plans for the area under its jurisdiction, and protect the Upper Mississippi River from uncontrolled and unplanned development through the preparation and adoption of a comprehensive management plan for the river and adjacent lands.

WHEREAS, the Mississippi Headwaters Board has been asked to and has been coordinating informational meetings of the dam tenders of the Mississippi Headwaters dams at Stump Lake, Cass Lake, Lake Winnibigoshish, Leech Lake and Pokegama.

NOW THEREFORE, BE IT RESOLVED that the Mississippi Headwaters Board opposes the drawdown of Headwaters lakes reservoirs on the Mississippi River for the purpose of replenishing water supplies in the Twin Cities metropolitan area and down river, unless all available conservation methods have been considered and implemented and the need for additional water is a necessity for public health, safety and welfare.

BE IT FURTHER RESOLVED that the Mississippi Headwaters Board recommends that the State and metropolitan area work cooperatively with the counties on the Mississippi Headwaters to develop a plan for water quantity in the event of future droughts.

APPENDIX B

RESERVOIR RECOVERABILITY

AND

EXAMPLE PROJECTIONS OF LAKE LEVELS

ILLUSTRATIVE PROJECTIONS OF LAKE LEVELS

The examples and their respective tables are illustrations of the type of information that would be presented in the actual plates. The following is a brief summary of the calculation methods used in determining the effects of various releases from the headwaters reservoirs in a low flow situation. A rain-free period assumption was made for all three examples.

In illustrative example 1, all reservoirs have a July 1 starting elevation equivalent to their respective low normal summer pool elevation. This elevation is converted to its equivalent storage in acre-feet. From this storage value, evaporation losses are subtrated for the desired period (option 1), or evaporation losses plus minimum releases dictated by the current operating plan (option 2), or evaporational losses plus minimum releases plus any additional releases (option 3). Additional releases are calculated based on an equal drop in stage (x=0.17 foot) for each reservoir resulting in discharges totaling 330 cfs.

In illustrative example 2, the large lakes (Winnibigoshish, Leech, and Pokegama Lakes) have a July 1 starting elevation equivalent to their low normal summer pool elevations, while the small lakes (Sandy, Pine and Gull Lakes) are 1 foot below their respective low normal summer pool elevations.

Additional releases are calculated based on an equal drop in stage (x=.20 ft.) for each of the large reservoirs resulting in discharges totaling 330 cfs. The same procedure was followed as in example 1 for each day of the period. Gull Lake falls to its minimum pool elevation on July 1 and Sandy falls to its minimum pool elevation on August 18. The operating plan specifies that when minimum pool elevation is reached in a reservoir, minimum releases are to be cut by one-half for that reservoir. Minimum releases are cut in half for Gull and Sandy giving a combined project flow of only 250 cfs. Therefore, to maintain the desired combined project flow rate of 270 cfs, an extra 20 cfs was released from Winni.

In illustrative example 3, the initial condition is the reverse of example 2. Additional releases are calculated based on an equal drop in stage (x=1.16 ft.) for each of the small reservoirs resulting in discharges totaling 330 cfs. Again the same calculation procedure was followed as in example 1. Gull Lake falls to its minimum pool elevation on August 4 and Sandy falls to its minimum elevation on August 21. After these dates, the minimum releases for Gull and Sandy are cut in half with extra releases made from Winni to compensate for the difference. For this example, additional releases are also to be made from Gull and Sandy (120 cfs, 84 cfs respectively) and these are eliminated once Gull and Sandy reach their minimum pool elevations, hence the combined supplemental discharges total only 126 cfs. Therefore, to maintain the desired supplemental flow of 330 cfs, an extra 204 cfs was released from Winni. Winni was selected to supply the extra flows because it has the greatest storage and is the reservoir furthest from reaching its minimum pool elevation of all six reservoirs.

RECOVERABILITY OF LAKE LEVELS

Recoverability of lake levels for each of the illustrative examples was analyzed for five (Winni, Leech, Sandy, Pine, & Gull) of the six headwater reservoirs. Pokegama Reservoir was not included in the analysis since its inflows are influenced by releases made from Winnibigoshish and Leech reservoirs which complicate the analysis to the extent that is beyond the scope of this study. The following is a brief summary of the calculation methods used in determining the recoverability of lake levels for the five remaining reservoirs.

From each of the illustrative examples (1 thru 3) two October 1 elevations from each reservoir were obtained based on two options (option 2 = evaporation + minimum releases, option 3 = evaporation + minimum releases + additional releases). Each October 1 elevation was then converted to its equivalent volume in acre-feet. Next, the upper and lower normal summer pool elevations were converted to their respective volumes, again in acre-ft. The difference between the volume of the reservoir on Oct 1 and the volume of the reservoir at its lower normal summer pool level is the volume of water the reservoir needs to recover to its lower normal summer pool. The same methodology was applied to determine the volume needed for the reservoir to recover to its upper summer pool. All volumes were then converted to second-foot-days (SFD), for use with the frequency curves explained below.

Frequency curves for the period October 1 to May 31 were developed to determine the probability of a reservoir to recover to its normal summer pool levels. These curves were developed by adding all inflows for each October 1-May 31 period for each water year for the period of record of the reservoir. This process follows standard methods outlined in Bulletin 17B of the Hydrology Subcommittee's, Guidelines for Determining Flood Flow Frequency.

The volumes needed by each reservoir to recover to its normal summer pool levels were then compared with the frequency curves to determine their "Percent Chance of Exceedance". For example, a value of 90% would mean that there is a 90 percent chance in any given year, with the selected October 1 starting elevation, that the given ending elevation (upper normal summer pool or lower normal summer pool) will be reached or exceeded. In other words, there would be a 10 percent chance that the reservoir would not be refilled with the given conditions.

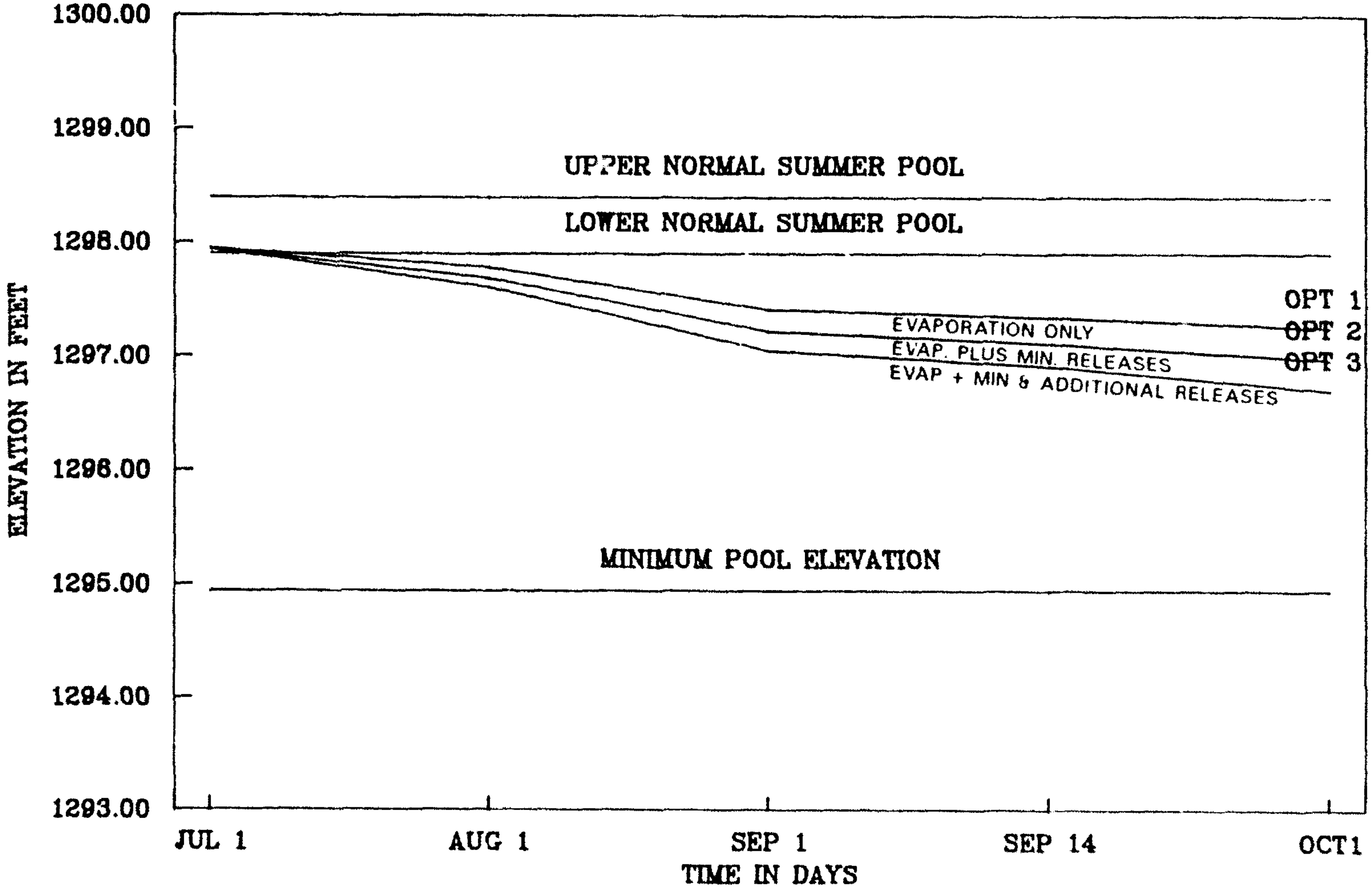
Since the frequency curves were not developed to go beyond 98 percent, the term 98+% used on the plates, reflect that the probability of refilling is greater than 98 percent in any given year with the given conditions.

The resulting probabilities are dependent on the starting conditions (October 1 pool elevation). Different probabilities would be obtained for different October 1 starting elevations. The resulting plates and their respective tables are illustrations of the process which would be completed when determining which types of actions should be taken during a low flow period requiring releases from any of the Headwaters Reservoirs.

ILLUSTRATIVE EXAMPLE 1

WINNIBIGOSHISH

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

LAKE WINNIBIGOSHISH

PERIOD FROM: JULY 1
TO: OCTOBER 1

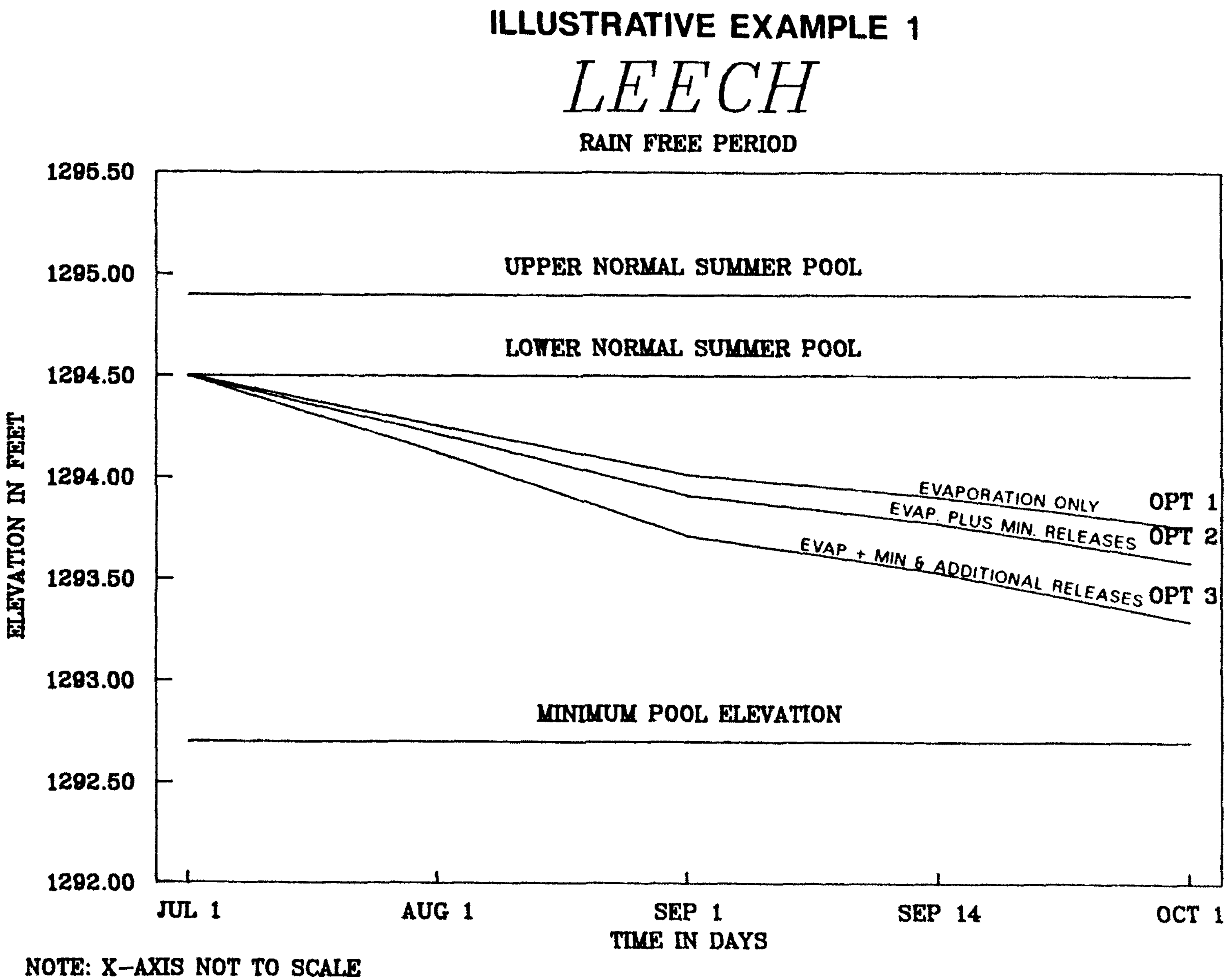
ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1297.94		
		-0.17	-0.17
AUGUST 1	1297.77		
		-0.37	-0.54
SEPTEMBER 1	1297.40		
		-0.07	-0.61
SEPTEMBER 14	1297.33		
		-0.09	-0.70
OCTOBER 1	1297.24		
OPTION 2: Evaporation plus minimum releases (100 cfs)			
JULY 1	1297.94		
		-0.26	-0.26
AUGUST 1	1297.68		
		-0.47	-0.73
SEPTEMBER 1	1297.21		
		-0.11	-0.84
SEPTEMBER 14	1297.10		
		-0.14	-0.98
OCTOBER 1	1296.96		
OPTION 3: Evaporation & min. releases & additional flows (90 cfs)			
JULY 1	1297.94		
		-0.34	-0.34
AUGUST 1	1297.60		
		-0.56	-0.89
SEPTEMBER 1	1297.04		
		-0.14	-1.03
SEPTEMBER 14	1296.90		
		-0.21	-1.24
OCTOBER 1	1296.69		

EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.


ILLUSTRATIVE EXAMPLE 1
LEECH
RAIN FREE PERIOD
1295.50
1295.00
1294.50
1294.00
1293.50
1293.00
1292.50
1292.00
ELEVATION IN FEET
UPPER NORMAL SUMMER POOL
LOWER NORMAL SUMMER POOL
EVAPORATION ONLY
OPT 1
EVAP. PLUS MIN. RELEASES
OPT 2
EVAP + MIN & ADDITIONAL RELEASES
OPT 3
MINIMUM POOL ELEVATION
JUL 1
AUG 1
SEP 1
SEP 14
OCT 1
TIME IN DAYS
NOTE: X-AXIS NOT TO SCALE

LEECH LAKE   PERIOD   FROM: JULY 1
                                                        TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1292.70
UPPER NORMAL SUMMER POOL = 1294.9
LOWER NORMAL SUMMER POOL = 1294.50

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1294.50		
		-0.25	-0.25
AUGUST 1	1294.25		
		-0.24	-0.49
SEPTEMBER 1	1294.01		
		-0.11	-0.60
SEPTEMBER 14	1293.90		
		-0.15	-0.75
OCTOBER 1	1293.75		
OPTION 2: Evaporation plus minimum releases (100 cfs)			
JULY 1	1294.50		
		-0.29	-0.26
AUGUST 1	1294.21		
		-0.30	-0.59
SEPTEMBER 1	1293.91		
		-0.14	-0.73
SEPTEMBER 14	1293.77		
		-0.19	-0.92
OCTOBER 1	1293.58		
OPTION 3: Evaporation & min. releases & additional flows (174 cfs)			
JULY 1	1294.50		
		-0.38	-0.38
AUGUST 1	1294.12		
		-0.41	-0.79
SEPTEMBER 1	1293.71		
		-0.18	-0.97
SEPTEMBER 14	1293.53		
		-0.24	-1.21
OCTOBER 1	1293.29		

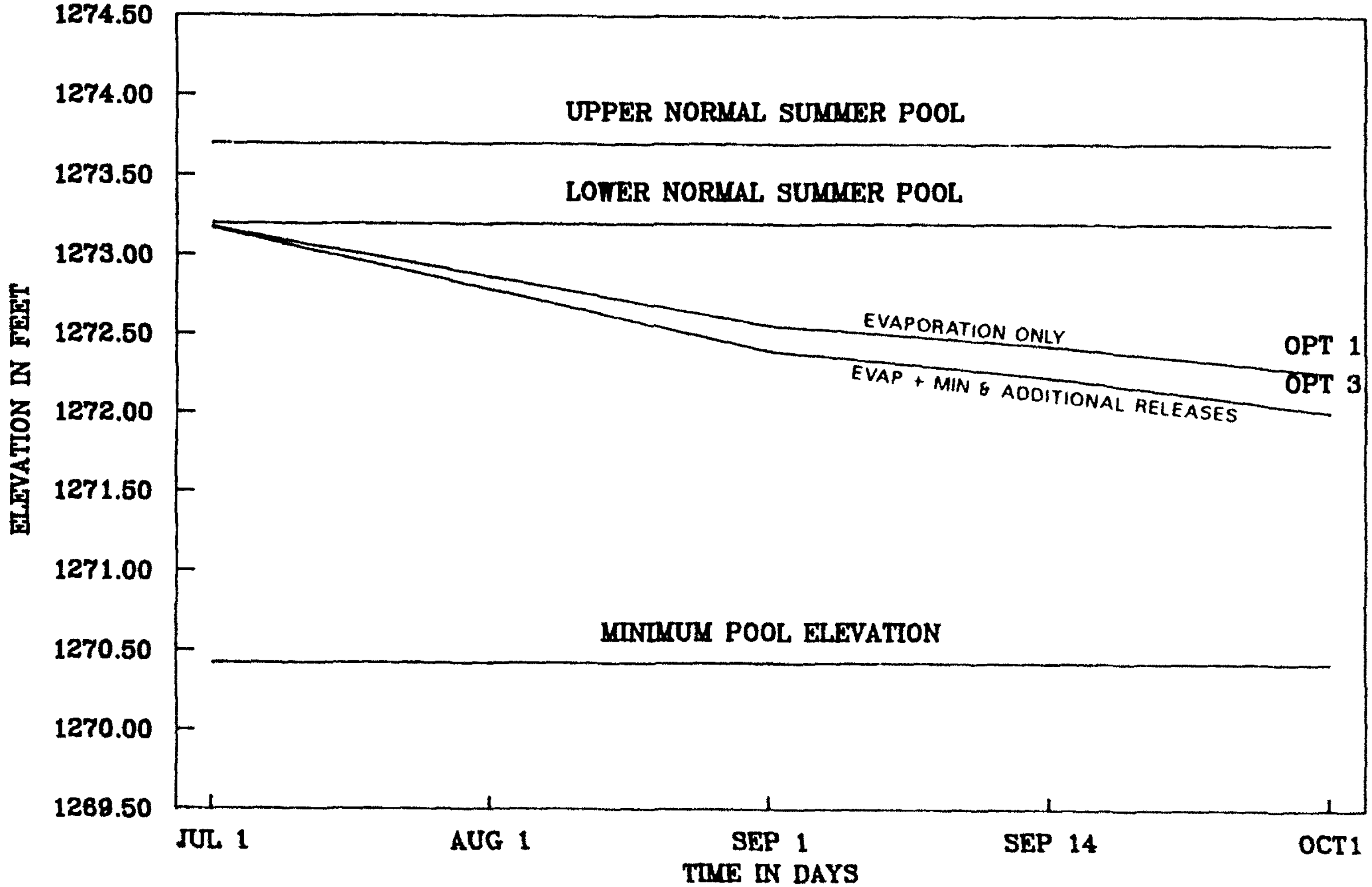
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 1

POKEGAMA

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

POKEGAMA LAKE

PERIOD FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1270.42
UPPER NORMAL SUMMER POOL = 1273.7
LOWER NORMAL SUMMER POOL = 1273.17

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1273.17		
		-0.31	-0.31
AUGUST 1	1272.86		
		-0.31	-0.62
SEPTEMBER 1	1272.55		
		-0.13	-0.75
SEPTEMBER 14	1272.42		
		-0.17	-0.92
OCTOBER 1	1272.25		
OPTION 2: Evaporation plus minimum releases (see note)			
JULY 1	1273.17		
		-0.31	-0.31
AUGUST 1	1272.86		
		-0.31	-0.62
SEPTEMBER 1	1272.55		
		-0.13	-0.75
SEPTEMBER 14	1272.42		
		-0.17	-0.92
OCTOBER 1	1272.25		
OPTION 3: Evaporation & min. releases & additional flows (20cfs)			
JULY 1	1273.17		
		-0.39	-0.39
AUGUST 1	1272.78		
		-0.39	-0.78
SEPTEMBER 1	1272.39		
		-0.17	-0.95
SEPTEMBER 14	1272.22		
		-0.22	-1.17
OCTOBER 1	1272.00		

MINIMUM DISCHARGE IS EQUAL TO THE DISCHARGE OF 220 CFS MINUS THE INFLOW OF 220 CFS FROM LAKE WINNIBIGOSHISH AND LEECH LAKE.

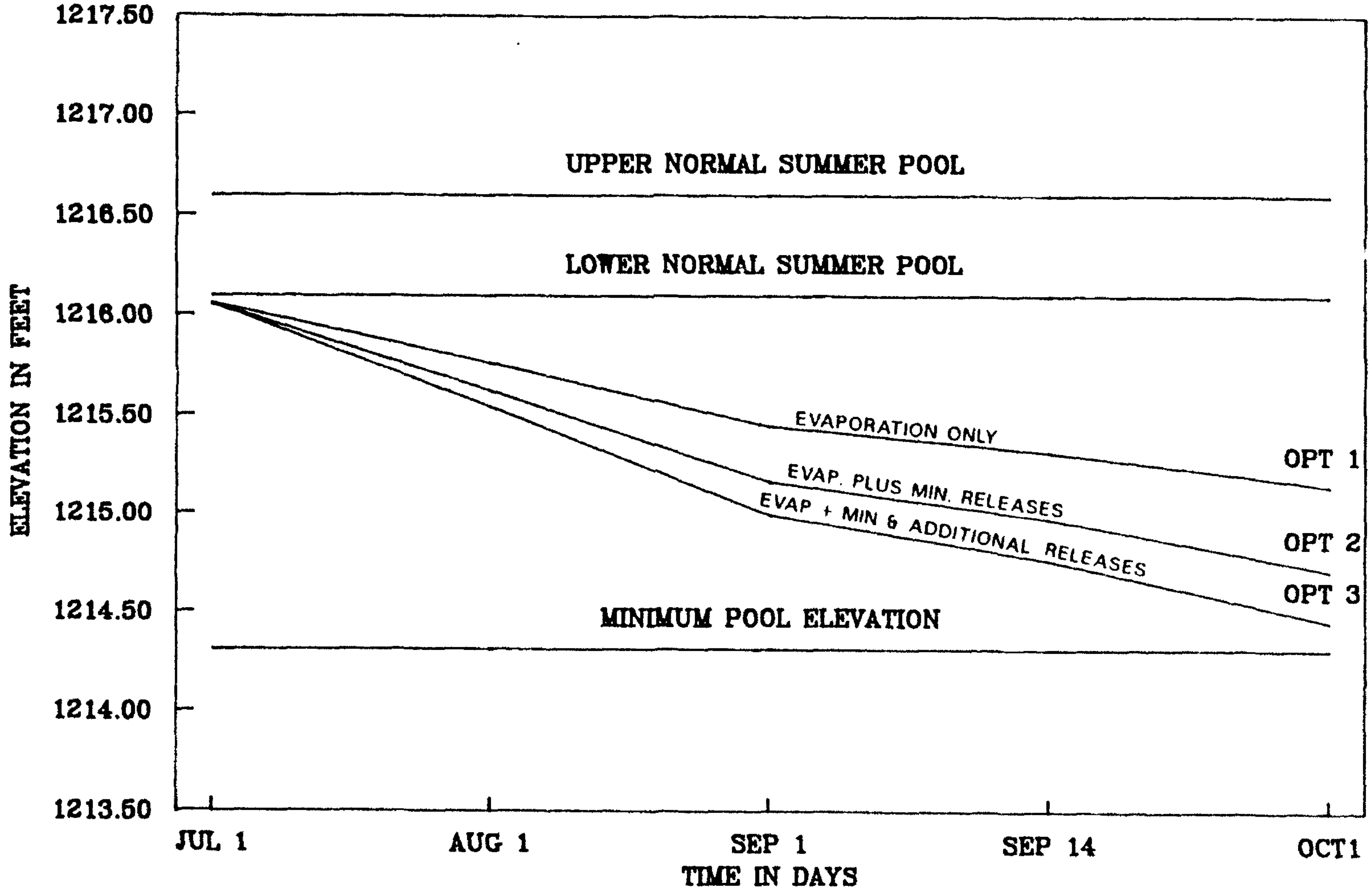
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 1

SANDY

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

SANDY LAKE

PERIOD FROM: JULY 1
TO: OCTOBER1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1216.06		
		-0.30	-0.30
AUGUST 1	1215.76		
		-0.32	-0.62
SEPTEMBER 1	1215.44		
		-0.13	-0.75
SEPTEMBER 14	1215.31		
		-0.17	-0.92
OCTOBER 1	1215.14		
OPTION 2: Evaporation plus minimum releases (20 cfs)			
JULY 1	1216.06		
		-0.44	-0.44
AUGUST 1	1215.62		
		-0.46	-0.90
SEPTEMBER 1	1215.16		
		-0.19	-1.09
SEPTEMBER 14	1214.97		
		-0.28	-1.37
OCTOBER 1	1214.71		
OPTION 3: Evaporation & min. releases & additional flows (12c[illegible])			
JULY 1	1216.06		
		-0.52	-0.52
AUGUST 1	1215.54		
		-0.55	-1.07
SEPTEMBER 1	1214.99		
		-0.23	-1.30
SEPTEMBER 14	1214.76		
		-0.31	-1.61
OCTOBER 1	1214.45		

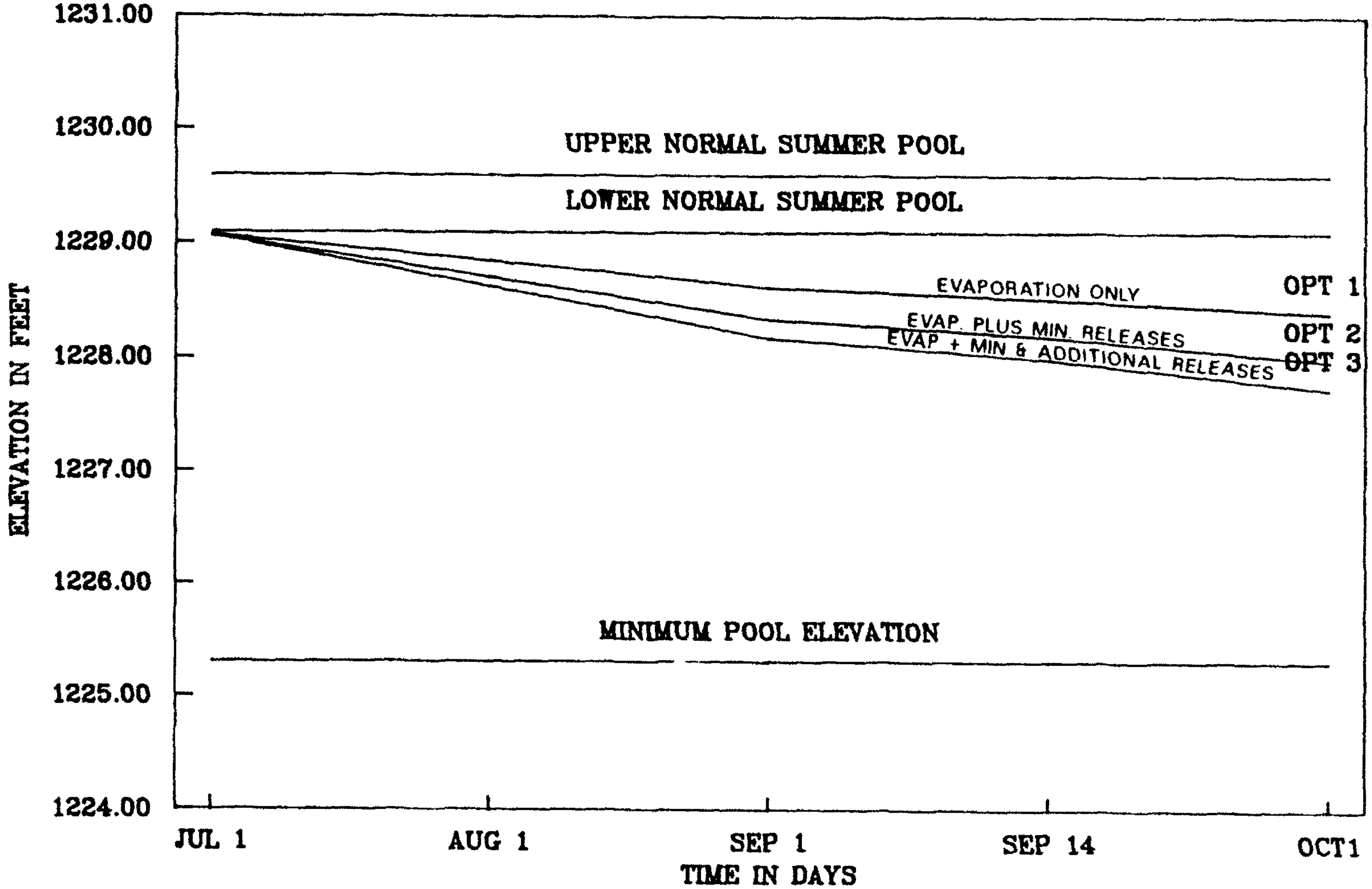
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 1

PINE

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

PINE RIVER | PERIOD FROM: JULY 1 TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1229.07		
		-0.23	-0.23
AUGUST 1	1228.84		
		-0.23	-0.46
SEPTEMBER 1	1228.61		
		-0.10	-0.56
SEPTEMBER 14	1228.51		
		-0.12	-0.68
OCTOBER 1	1228.39		
OPTION 2: Evaporation plus minimum releases (30 cfs)			
JULY 1	1229.07		
		-0.37	-0.37
AUGUST 1	1228.70		
		-0.37	-0.74
SEPTEMBER 1	1228.33		
		-0.15	-0.89
SEPTEMBER 14	1228.18		
		-0.21	-1.10
OCTOBER 1	1227.97		
OPTION 3: Evaporation & min. releases & additional flows (18 cfs)			
JULY 1	1229.07		
		-0.45	-0.45
AUGUST 1	1228.62		
		-0.45	-0.90
SEPTEMBER 1	1228.17		
		-0.19	-1.09
SEPTEMBER 14	1227.98		
		-0.26	-1.35
OCTOBER 1	1227.72		

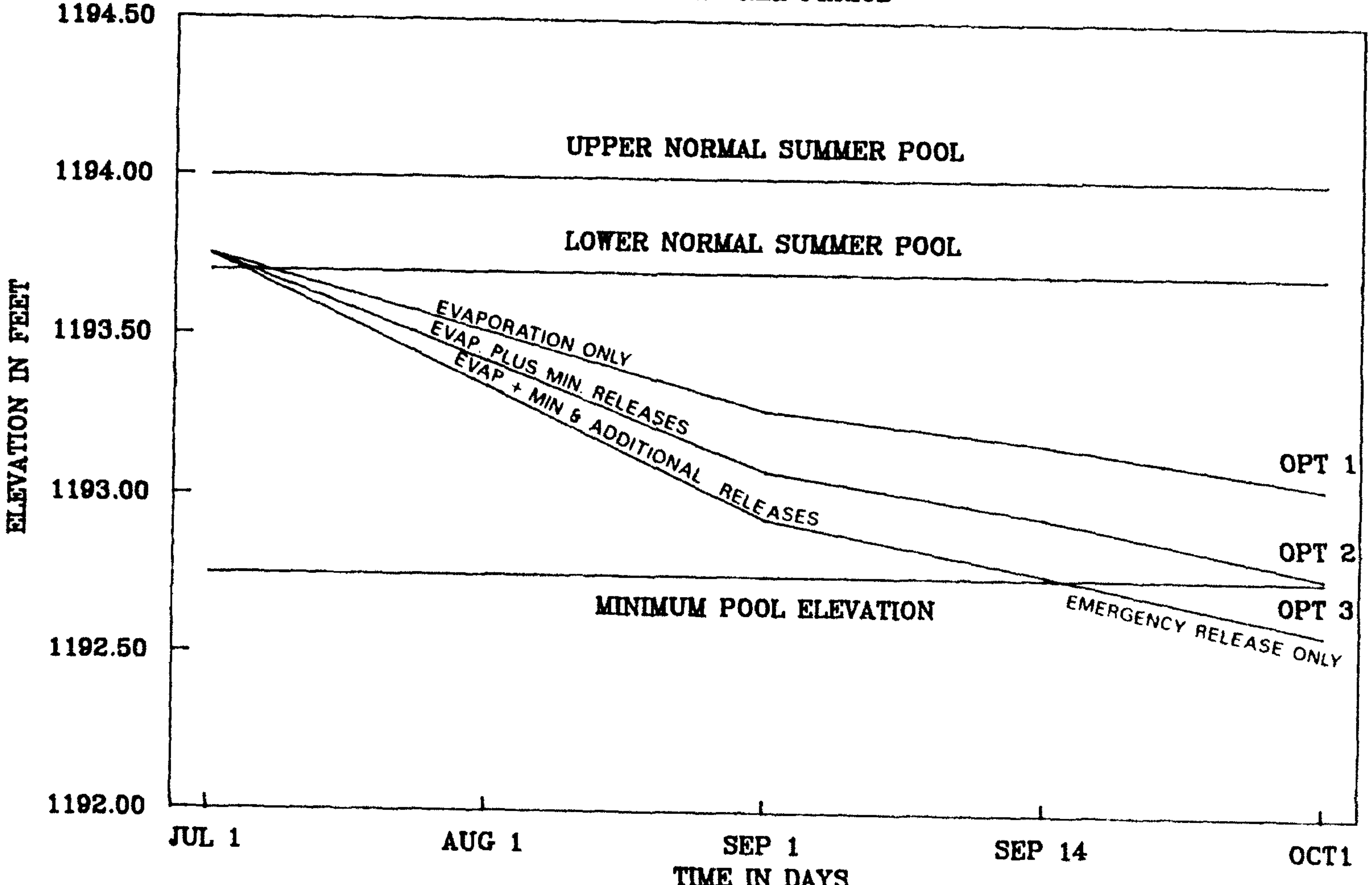
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 1

GULL

RAIN FREE PERIOD



NOTE: X–AXIS NOT TO SCALE

GULL LAKE

PERIOD FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS. SUMMER BANDS. WINNI, LEECH, & POKE

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1193.75		
		-0.24	-0.24
AUGUST 1	1193.51		
		-0.24	-0.48
SEPTEMBER 1	1193.27		
		-0.10	-0.58
SEPTEMBER 14	1193.17		
		-0.13	-0.71
OCTOBER 1	1193.04		
OPTION 2: Evaporation plus minimum releases (20 cfs)			
JULY 1	1193.75		
		-0.33	-0.33
AUGUST 1	1193.42		
		-0.32	-0.65
SEPTEMBER 1	1193.08		
		-0.14	-0.79
SEPTEMBER 14	1192.94		
		-0.18	-0.97
OCTOBER 1	1192.76		
OPTION 3: Evaporation & min. releases & additional flows (16 cfs --minimum pool elevation reached on September 14, min. releases cut by 1/2, no additional releases made.)			
JULY 1	1193.75		
		-0.41	-0.41
AUGUST 1	1193.34		
		-0.31	-0.72
SEPTEMBER 1	1192.93		
		-0.17	-0.89
SEPTEMBER 14	1192.76		
		-0.18	-1.07
OCTOBER 1	1192.58		

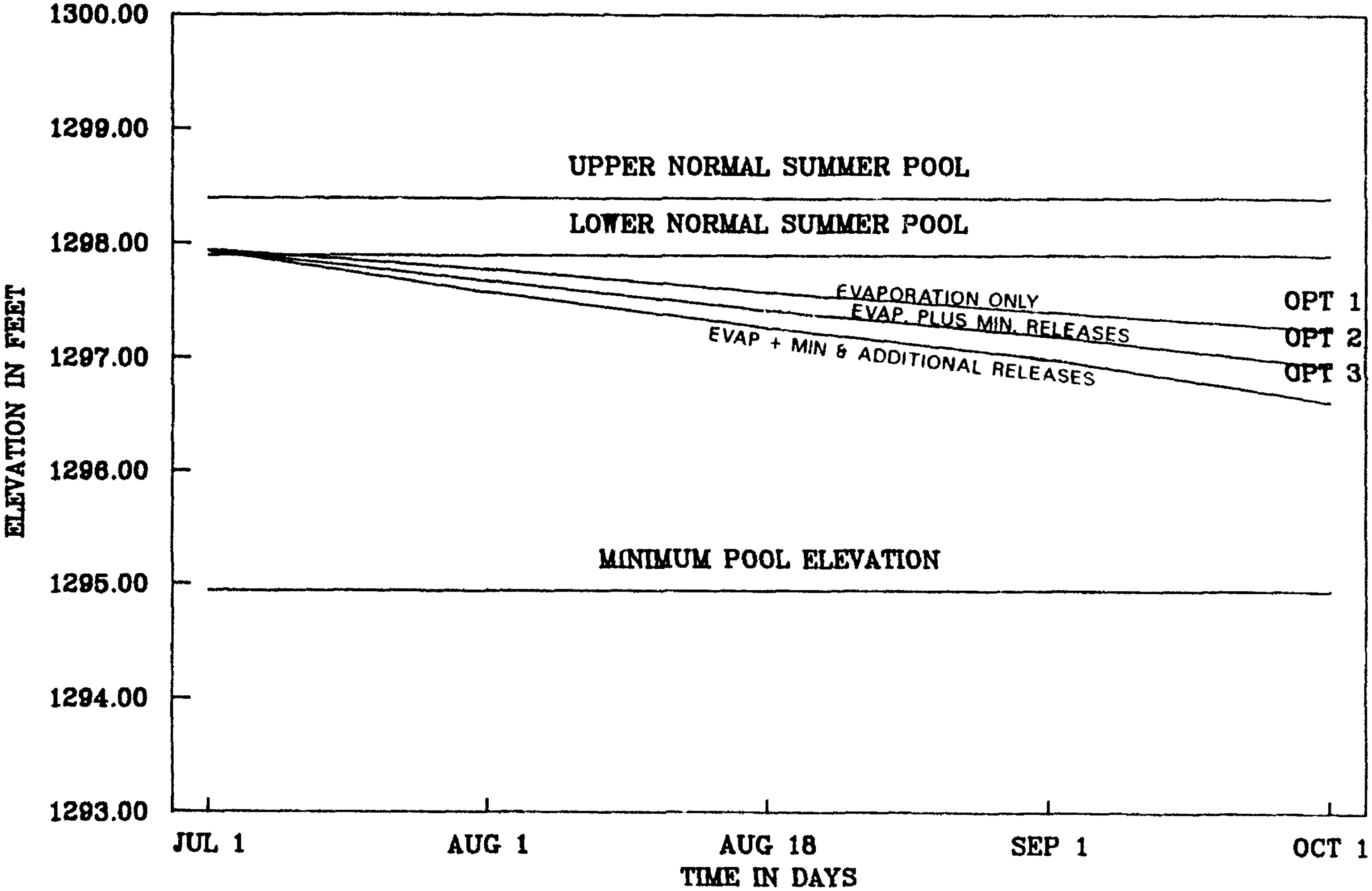
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 2

WINNIBIGOSHISH

RAIN FREE PERIOD



NOTE: X–AXIS NOT TO SCALE

LAKE WINNIBIGOSHISH

PERIOD FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1297.94		
		-0.17	-0.17
AUGUST 1	1297.77		
		-0.20	-0.37
AUGUST 18	1297.57		
		-0.17	-0.54
SEPTEMBER 1	1297.40		
		-0.16	-0.80
OCTOBER 1	1297.24		
OPTION 2: Evaporation plus minimum releases (100 cfs + 10 cfs from Gull after July 1, + 10 cfs from Sandy after August 18).			
JULY 1	1297.94		
		-0.27	-0.27
AUGUST 1	1297.67		
		-0.26	-0.53
AUGUST 18	1297.41		
		-0.22	-0.75
SEPTEMBER 1	1297.19		
		-0.27	-1.02
OCTOBER 1	1296.92		
OPTION 3: Evaporation & min. releases & additional flows (105 cfs)			
JULY 1	1297.94		
		-0.37	-0.37
AUGUST 1	1297.57		
		-0.31	-0.68
AUGUST 18	1297.26		
		-0.27	-0.95
SEPTEMBER 1	1296.99		
		-0.38	-1.33
OCTOBER 1	1296.61		

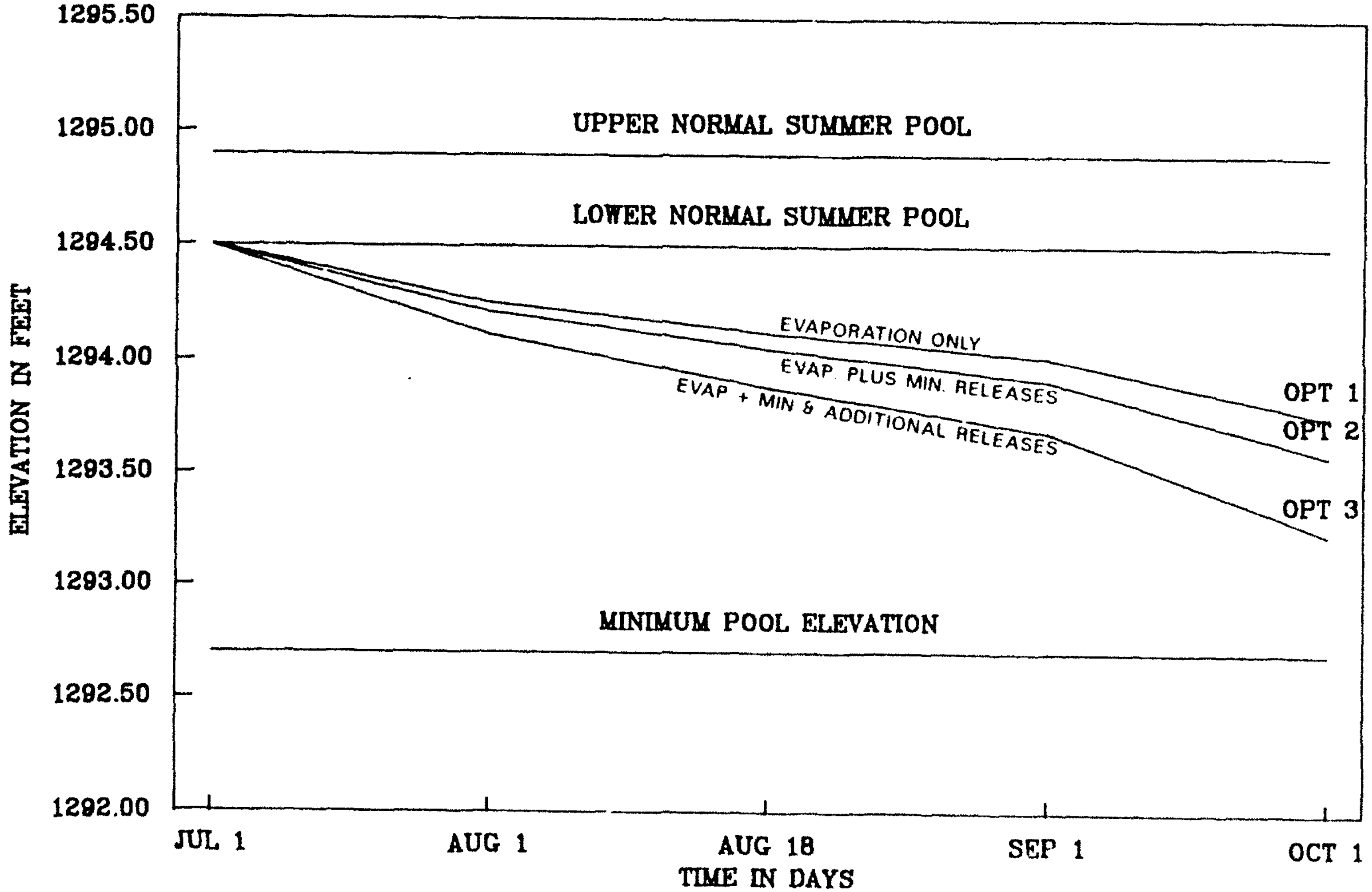
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 2

LEECH

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

LEECH LAKE | PERIOD FROM: JULY 1 TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1292.70
UPPER NORMAL SUMMER POOL = 1294.9
LOWER NORMAL SUMMER POOL = 1294.50

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1294.50		
		-0.25	-0.25
AUGUST 1	1294.25		
		-0.13	-0.38
AUGUST 18	1294.12		
		-0.11	-0.49
SEPTEMBER 1	1294.01		
		-0.26	-0.75
OCTOBER 1	1293.75		
OPTION 2: Evaporation plus minimum releases (100 cfs)			
JULY 1	1294.50		
		-0.29	-0.29
AUGUST 1	1294.21		
		-0.16	-0.45
AUGUST 18	1294.05		
		-0.14	-0.59
SEPTEMBER 1	1293.91		
		-0.33	-0.92
OCTOBER 1	1293.58		
OPTION 3: Evaporation & min. releases & additional flows (205 cfs)			
JULY 1	1294.50		
		-0.39	-0.39
AUGUST 1	1294.11		
		-0.23	-0.62
AUGUST 18	1293.88		
		-0.20	-0.82
SEPTEMBER 1	1293.68		
		-0.45	-1.27
OCTOBER 1	1293.23		

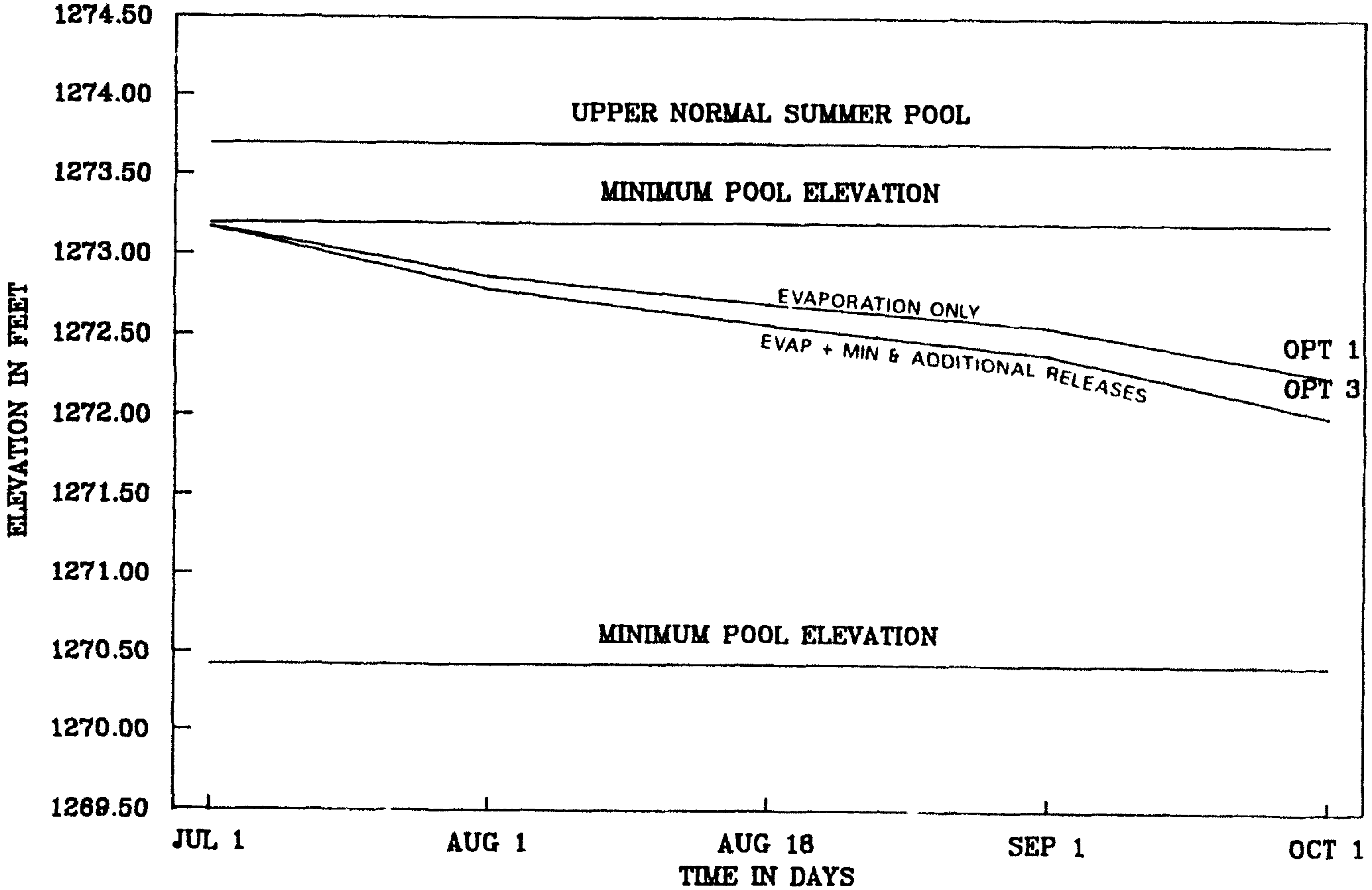
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 2

POKEGAMA

RAIN FREE PERIOD



NOTE: X–AXIS NOT TO SCALE

POKEGAMA LAKE — PERIOD FROM: JULY 1 TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1270.42
UPPER NORMAL SUMMER POOL = 1273.7
LOWER NORMAL SUMMER POOL = 1273.17

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1273.17		
		-0.31	-0.31
AUGUST 1	1272.86		
		-0.17	-0.48
AUGUST 18	1272.69		
		-0.14	-0.62
SEPTEMBER 1	1272.55		
		-0.30	-0.92
OCTOBER 1	1272.25		
OPTION 2: Evaporation plus minimum releases (see note)			
JULY 1	1273.17		
		-0.31	-0.31
AUGUST 1	1272.86		
		-0.17	-0.48
AUGUST 18	1272.69		
		-0.14	-0.62
SEPTEMBER 1	1272.55		
		-0.30	-0.92
OCTOBER 1	1272.25		
OPTION 3: Evaporation & min. releases & additional flows (20 cfs)			
JULY 1	1273.17		
		-0.39	-0.39
AUGUST 1	1272.78		
		-0.22	-0.61
AUGUST 18	1272.56		
		-0.18	-0.79
SEPTEMBER 1	1272.38		
		-0.38	-1.17
OCTOBER 1	1272.00		

MINIMUM DISCHARGE IS EQUAL TO THE DISCHARGE OF 220 CFS MINUS THE INFLOW OF 220 CFS FROM LAKE WINNIBIGOSHISH AND LEECH LAKE.

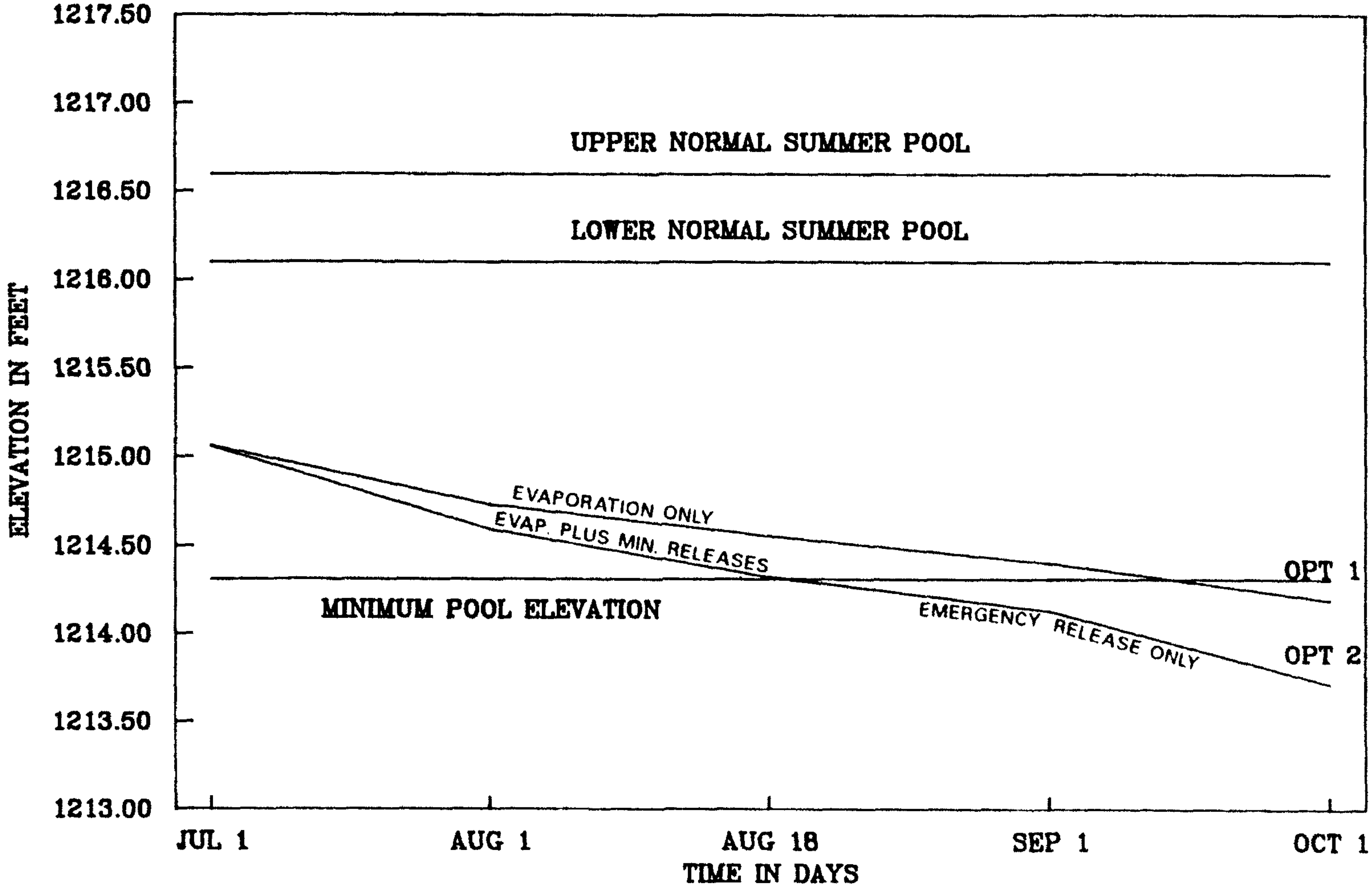
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 2

SANDY

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

SANDY LAKE

PERIOD FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1215.06		
		-0.33	-0.33
AUGUST 1	1214.73		
		-0.18	-0.51
AUGUST 18	1214.55		
		-0.15	-0.66
SEPTEMBER 1	1214.40		
		-0.21	-0.87
OCTOBER 1	1214.19		
OPTION 2: Evaporation plus minimum releases (20 cfs --minimum pool elevation reached on Aug 18, releases cut by 1/2)			
JULY 1	1215.06		
		-0.47	-0.47
AUGUST 1	1214.59		
		-0.27	-0.74
AUGUST 18	1214.32		
		-0.19	-0.93
SEPTEMBER 1	1214.13		
		-0.42	-1.35
OCTOBER 1	1213.71		
OPTION 3: Evaporation & min. releases & additional flows (none)			
JULY 1	1215.06		
		-0.47	-0.47
AUGUST 1	1214.59		
		-0.27	-0.74
AUGUST 18	1214.32		
		-0.19	-0.93
SEPTEMBER 1	1214.13		
		-0.42	-1.35
OCTOBER 1	1213.71		

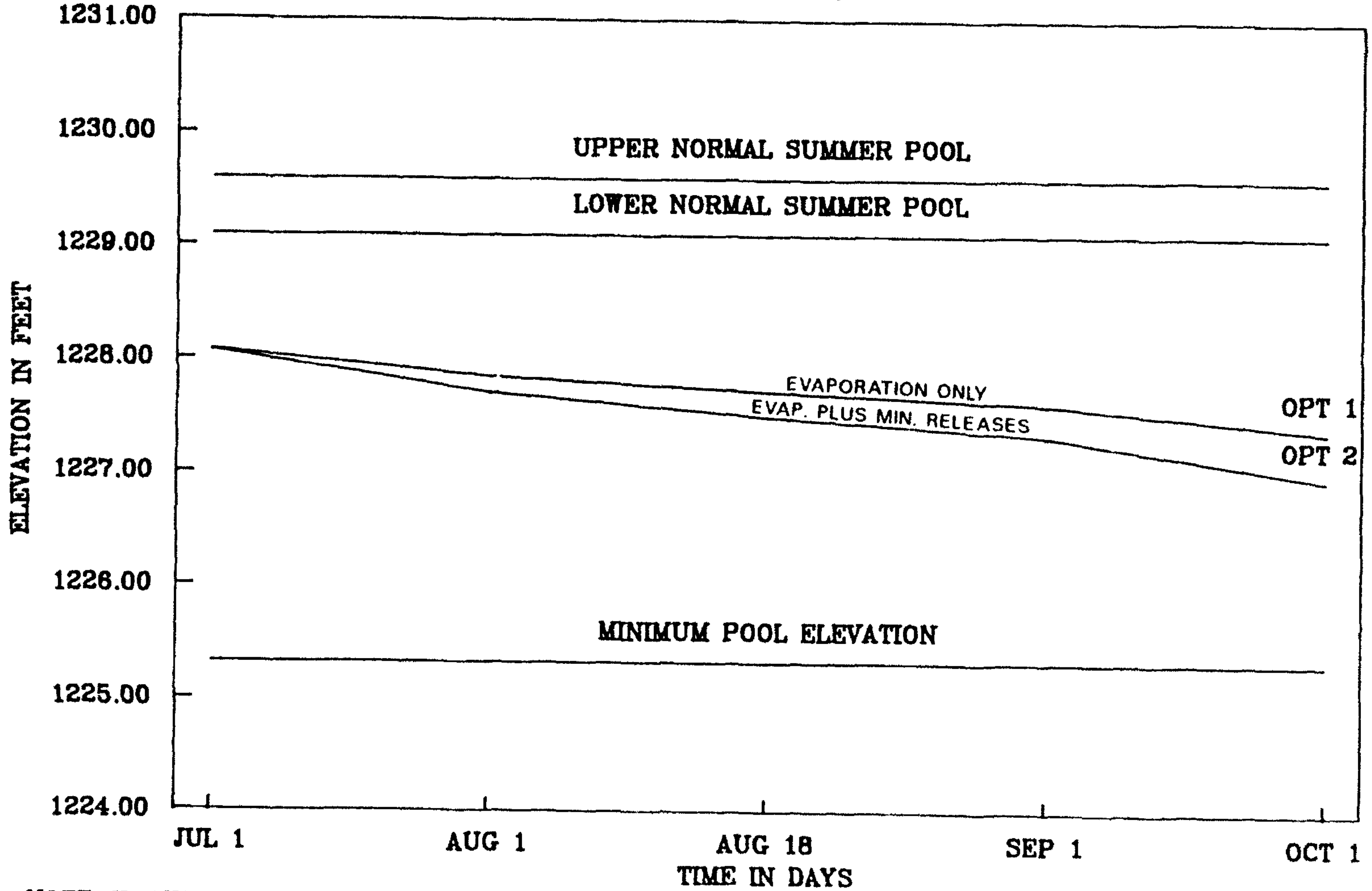
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 2

PINE

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

PINE RIVER

PERIOD FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1228.07		
		-0.23	-0.23
AUGUST 1	1227.84		
		-0.13	-0.36
AUGUST 18	1227.71		
		-0.11	-0.48
SEPTEMBER 1	1227.60		
		-0.23	-0.71
OCTOBER 1	1227.37		
OPTION 2: Evaporation plus minimum releases (30 cfs)			
JULY 1	1228.07		
		-0.37	-0.37
AUGUST 1	1227.70		
		-0.21	-0.58
AUGUST 18	1227.49		
		-0.17	-0.75
SEPTEMBER 1	1227.32		
		-0.37	-1.12
OCTOBER 1	1226.95		
OPTION 3: Evaporation & min. releases & additional flows (none)			
JULY 1	1228.07		
		-0.37	-0.37
AUGUST 1	1227.70		
		-0.21	-0.58
AUGUST 18	1227.49		
		-0.17	-0.75
SEPTEMBER 1	1227.32		
		-0.37	-1.12
OCTOBER 1	1226.95		

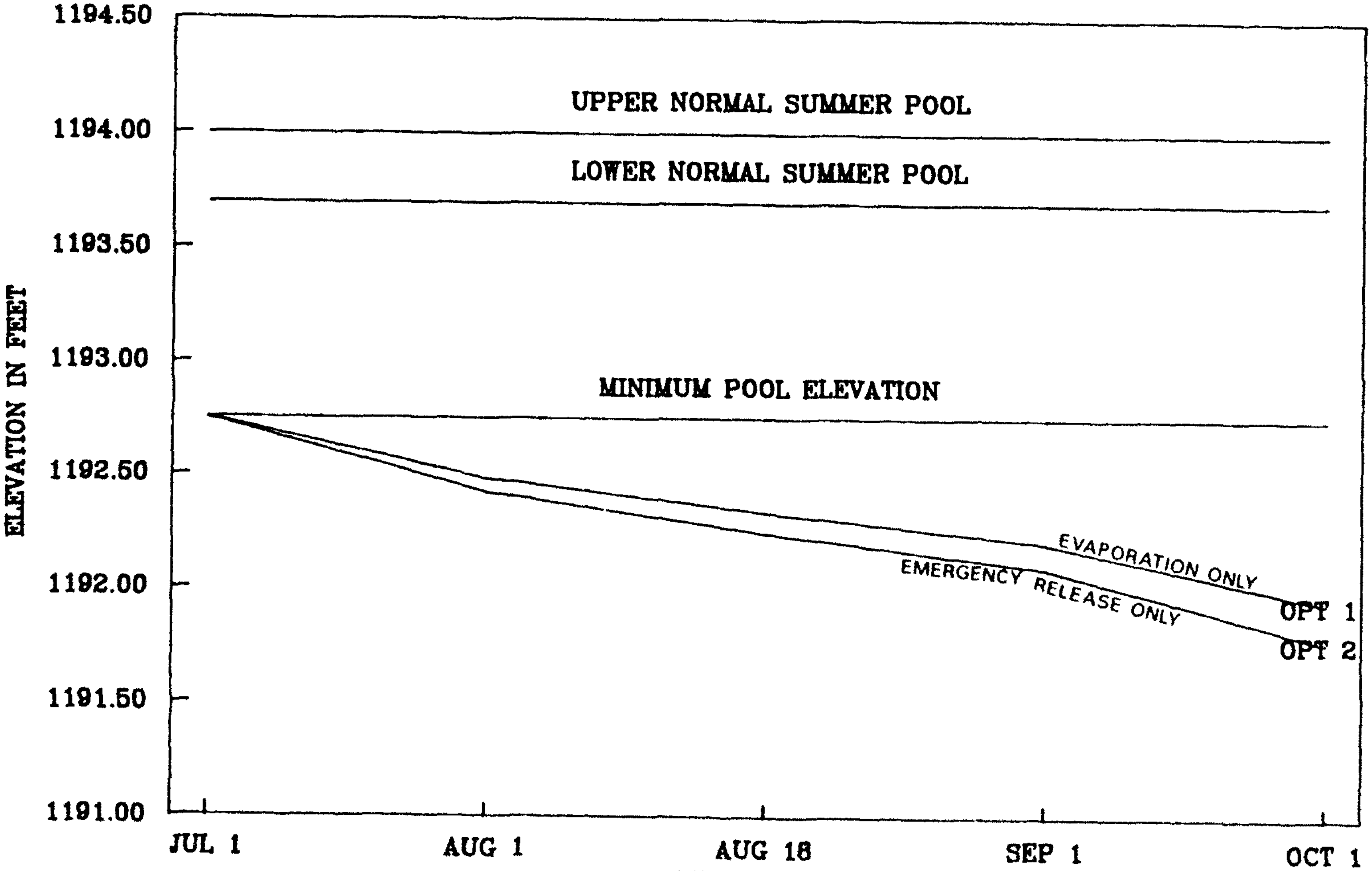
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 2

GULL

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

GULL LAKE   PERIOD   FROM: JULY 1
TO: OCTOBER 1

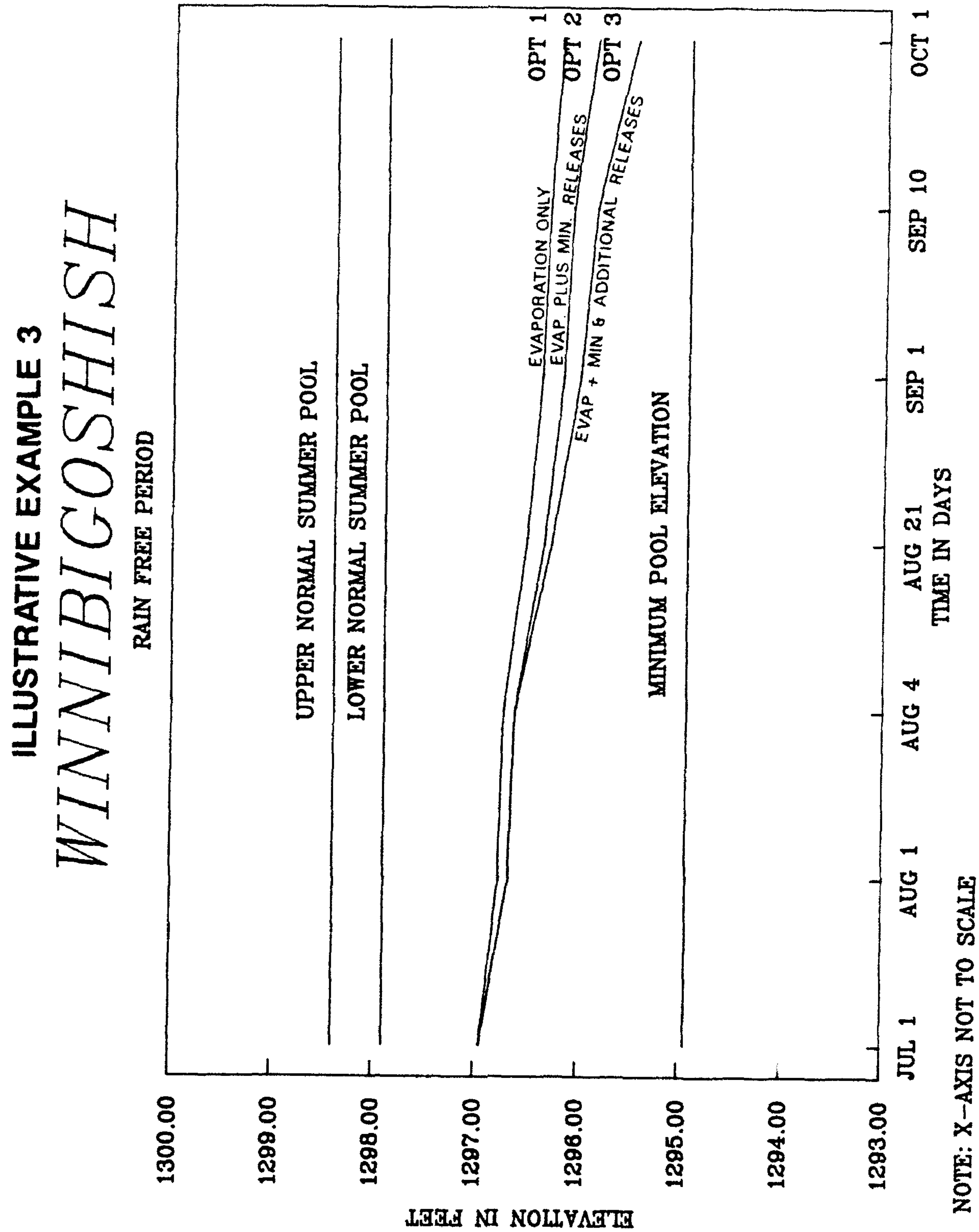
ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1192.75		
		-0.27	-0.27
AUGUST 1	1192.48		
		-0.15	-0.42
AUGUST 18	1192.33		
		-0.13	-0.55
SEPTEMBER 1	1192.20		
		-0.26	-0.81
OCTOBER 1	1191.94		
OPTION 2: Evaporation plus minimum releases (20 cfs--minimum pool elevation reached on Jul 1, releases cut by 1/2)			
JULY 1	1192.75		
		-0.33	-0.33
AUGUST 1	1192.42		
		-0.18	-0.51
AUGUST 18	1192.24		
		-0.15	-0.66
SEPTEMBER 1	1192.09		
		-0.32	-0.98
OCTOBER 1	1191.77		
OPTION 3: Evaporation & min. releases & additional flows (none)			
JULY 1	1192.75		
		-0.33	-0.33
AUGUST 1	1192.42		
		-0.18	-0.51
AUGUST 18	1192.24		
		-0.15	-0.66
SEPTEMBER 1	1192.09		
		-0.32	-0.98
OCTOBER 1	1191.77		

EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.



ILLUSTRATIVE EXAMPLE 3
WINNIBIGOSHISH
RAIN FREE PERIOD
UPPER NORMAL SUMMER POOL
LOWER NORMAL SUMMER POOL
MINIMUM POOL ELEVATION
EVAPORATION ONLY
EVAP. PLUS MIN. RELEASES
EVAP + MIN & ADDITIONAL RELEASES
OPT 1
OPT 2
OPT 3
ELEVATION IN FEET
1300.00
1299.00
1298.00
1297.00
1296.00
1295.00
1294.00
1293.00
JUL 1
AUG 1
AUG 4
AUG 21
SEP 1
SEP 10
OCT 1
TIME IN DAYS
NOTE: X-AXIS NOT TO SCALE

LAKE WINNIBIGOSHISH PERIOD FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1296.94		
		-0.17	-0.17
AUGUST 1	1296.77		
		-0.04	-0.21
AUGUST 4	1296.73		
		-0.22	-0.43
AUGUST 21	1296.51		
		-0.14	-0.57
SEPTEMBER 1	1296.37		
		-0.06	-0.63
SEPTEMBER 10	1296.31		
		-0.12	-0.75
OCTOBER 1	1296.19		
OPTION 2: Evaporation plus minimum releases (100 cfs)			
JULY 1	1296.94		
		-0.27	-0.27
AUGUST 1	1296.67		
		-0.04	-0.31
AUGUST 4	1296.62		
		-0.28	-0.59
AUGUST 21	1296.34		
		-0.19	-0.78
SEPTEMBER 1	1296.16		
		-0.08	-0.86
SEPTEMBER 10	1296.08		
		-0.23	-1.09
OCTOBER 1	1295.85		
OPTION 3: Evaporation & min. releases & additional flows (+ 130 cfs from Gull after Aug 4, +94 cfs fron Sandy after Aug 21).			
JULY 1	1296.94		
		-0.27	-0.27
AUGUST 1	1296.67		
		-0.05	-0.32
AUGUST 4	1296.62		
		-0.35	-0.67
AUGUST 21	1296.27		
		-0.27	-0.94
SEPTEMBER 1	1296.00		
		-0.15	-1.09
SEPTEMBER 10	1295.85		
		-0.39	-1.48
OCTOBER 1	1295.46		

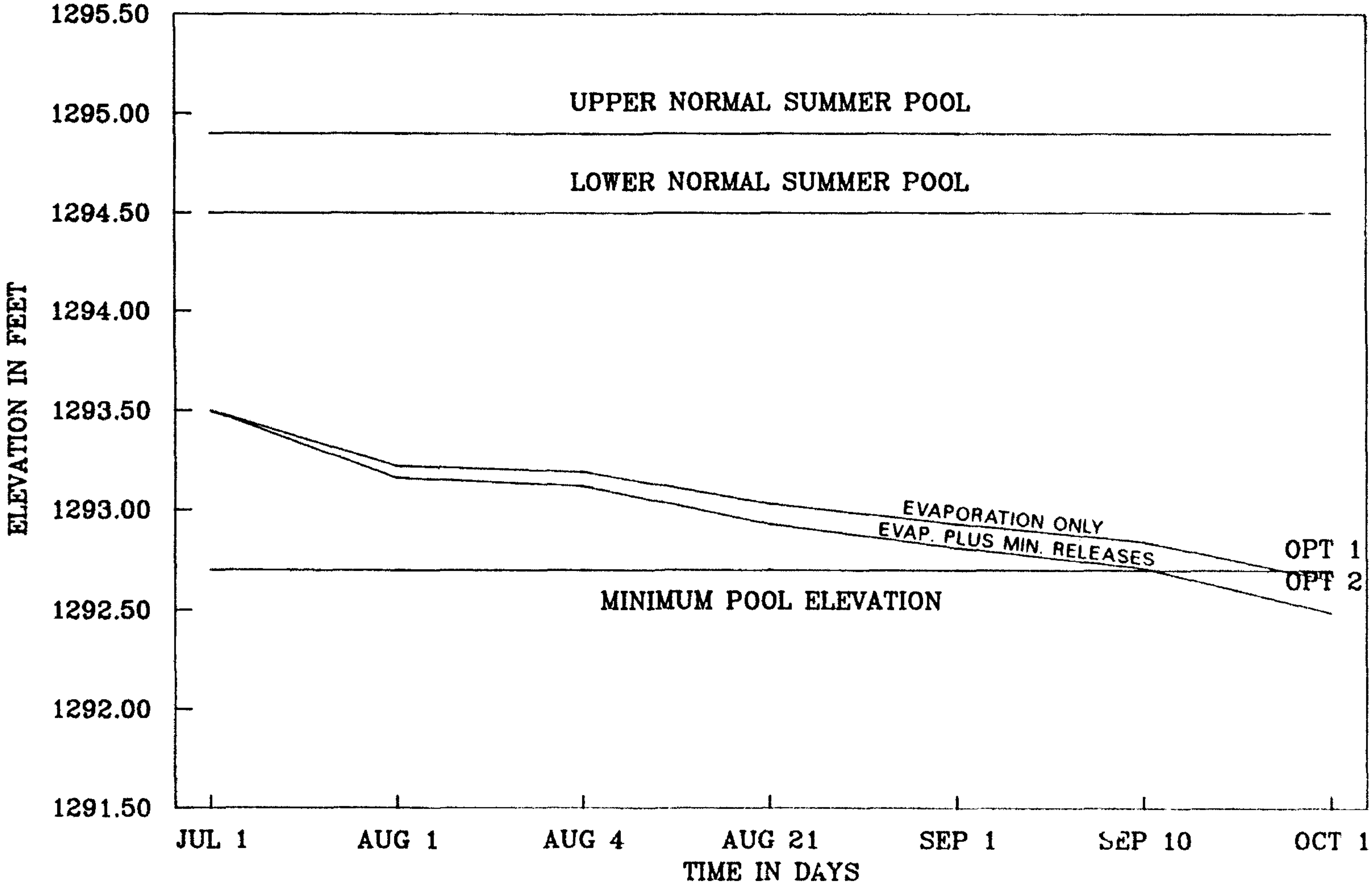
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 3

LEECH

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

LEECH LAKE　　　　　　PERIOD　FROM: JULY 1
　　　　　　　　　　　　　　　TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1292.70
UPPER NORMAL SUMMER POOL = 1294.9
LOWER NORMAL SUMMER POOL = 1294.50

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1293.50		
		-0.28	-0.28
AUGUST 1	1293.22		
		-0.03	-0.31
AUGUST 4	1293.19		
		-0.16	-0.47
AUGUST 21	1293.03		
		-0.10	-0.57
SEPTEMBER 1	1292.93		
		-0.09	-0.66
SEPTEMBER 10	1292.84		
		-0.19	-0.85
OCTOBER 1	1292.65		
OPTION 2: Evaporation plus minimum releases (100 cfs)			
JULY 1	1293.50		
		-0.34	-0.34
AUGUST 1	1293.16		
		-0.04	-0.38
AUGUST 4	1293.12		
		-0.19	-0.57
AUGUST 21	1292.93		
		-0.12	-0.69
SEPTEMBER 1	1292.81		
		-0.10	-0.79
SEPTEMBER 10	1292.71		
		-0.22	-1.01
OCTOBER 1	1292.49		
OPTION 3: Evaporation & min. releases & additional flows (none)			
JULY 1	1293.50		
		-0.34	-0.34
AUGUST 1	1293.16		
		-0.04	-0.38
AUGUST 4	1293.12		
		-0.19	-0.57
AUGUST 21	1292.93		
		-0.12	-0.69
SEPTEMBER 1	1292.81		
		-0.10	-0.79
SEPTEMBER 10	1292.71		
		-0.22	-1.01
OCTOBER 1	1292.49		

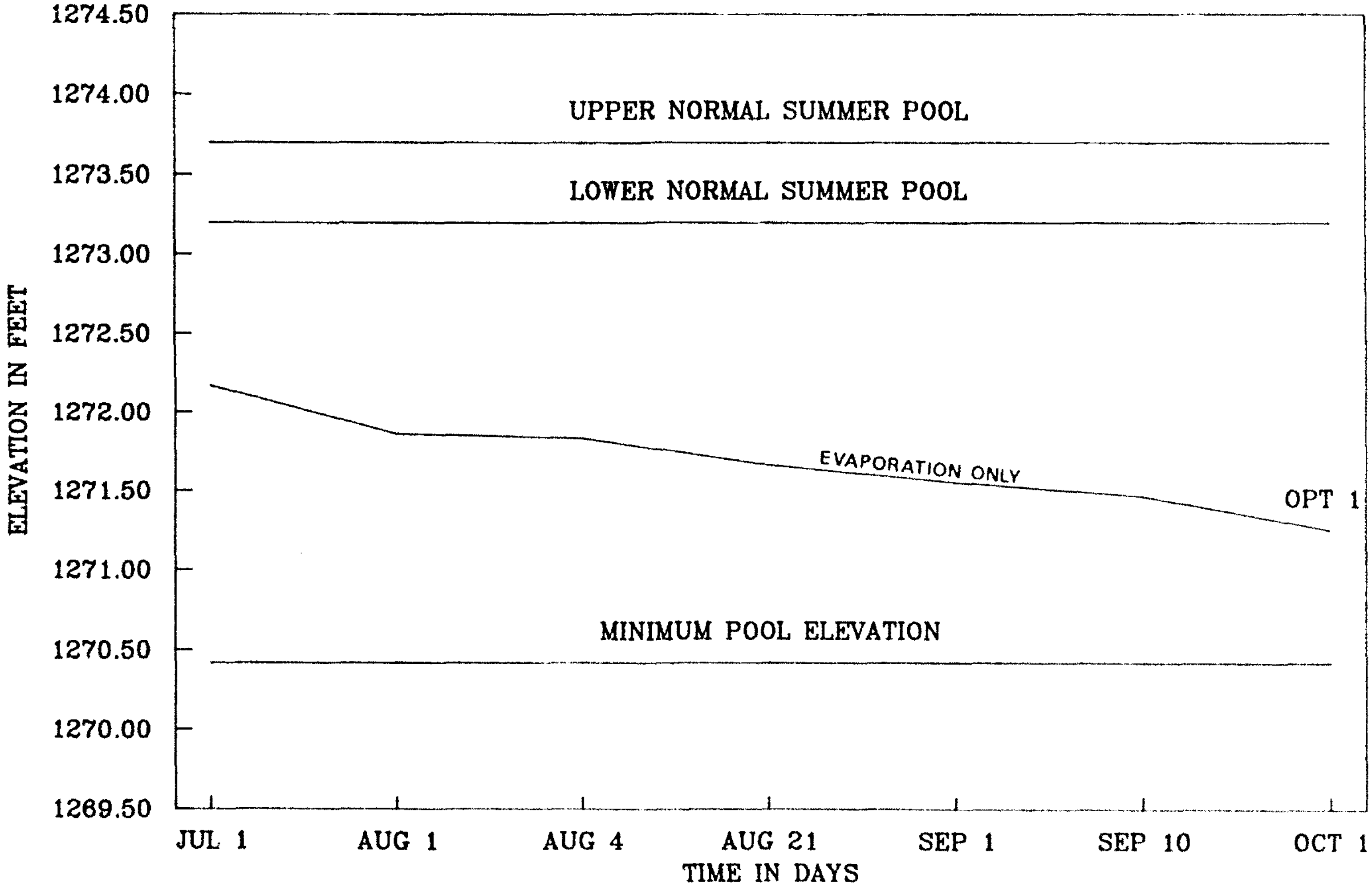
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 3

POKEGAMA

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

POKEGAMA LAKE   PERIOD   FROM: JULY 1
                                                                                        TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1270.42
UPPER NORMAL SUMMER POOL = 1273.7
LOWER NORMAL SUMMER POOL = 1273.17

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1272.17		
		-0.31	-0.31
AUGUST 1	1271.86		
		-0.03	-0.34
AUGUST 4	1271.83		
		-0.17	-0.51
AUGUST 21	1271.66		
		-0.11	-0.62
SEPTEMBER 1	1271.55		
		-0.09	-0.71
SEPTEMBER 10	1271.46		
		-0.21	-0.92
OCTOBER 1	1271.25		
OPTION 2: Evaporation plus minimum releases (see note)			
JULY 1	1272.17		
		-0.31	-0.31
AUGUST 1	1271.86		
		-0.03	-0.34
AUGUST 4	1271.83		
		-0.17	-0.51
AUGUST 21	1271.66		
		-0.11	-0.62
SEPTEMBER 1	1271.55		
		-0.09	-0.71
SEPTEMBER 10	1271.46		
		-0.21	-0.92
OCTOBER 1	1271.25		
OPTION 3: Evaporation & min. releases & additional flows (none)			
JULY 1	1272.17		
		-0.31	-0.31
AUGUST 1	1271.86		
		-0.03	-0.34
AUGUST 4	1271.83		
		-0.17	-0.51
AUGUST 21	1271.66		
		-0.11	-0.62
SEPTEMBER 1	1271.55		
		-0.09	-0.71
SEPTEMBER 10	1271.46		
		-0.21	-0.92
OCTOBER 1	1271.25		

MINIMUM DISCHARGE IS EQUAL TO THE DISCHARGE OF 220 CFS MINUS THE INFLOW OF 220 CFS FROM LAKE WINNIBIGOSHISH AND LEECH LAKE.

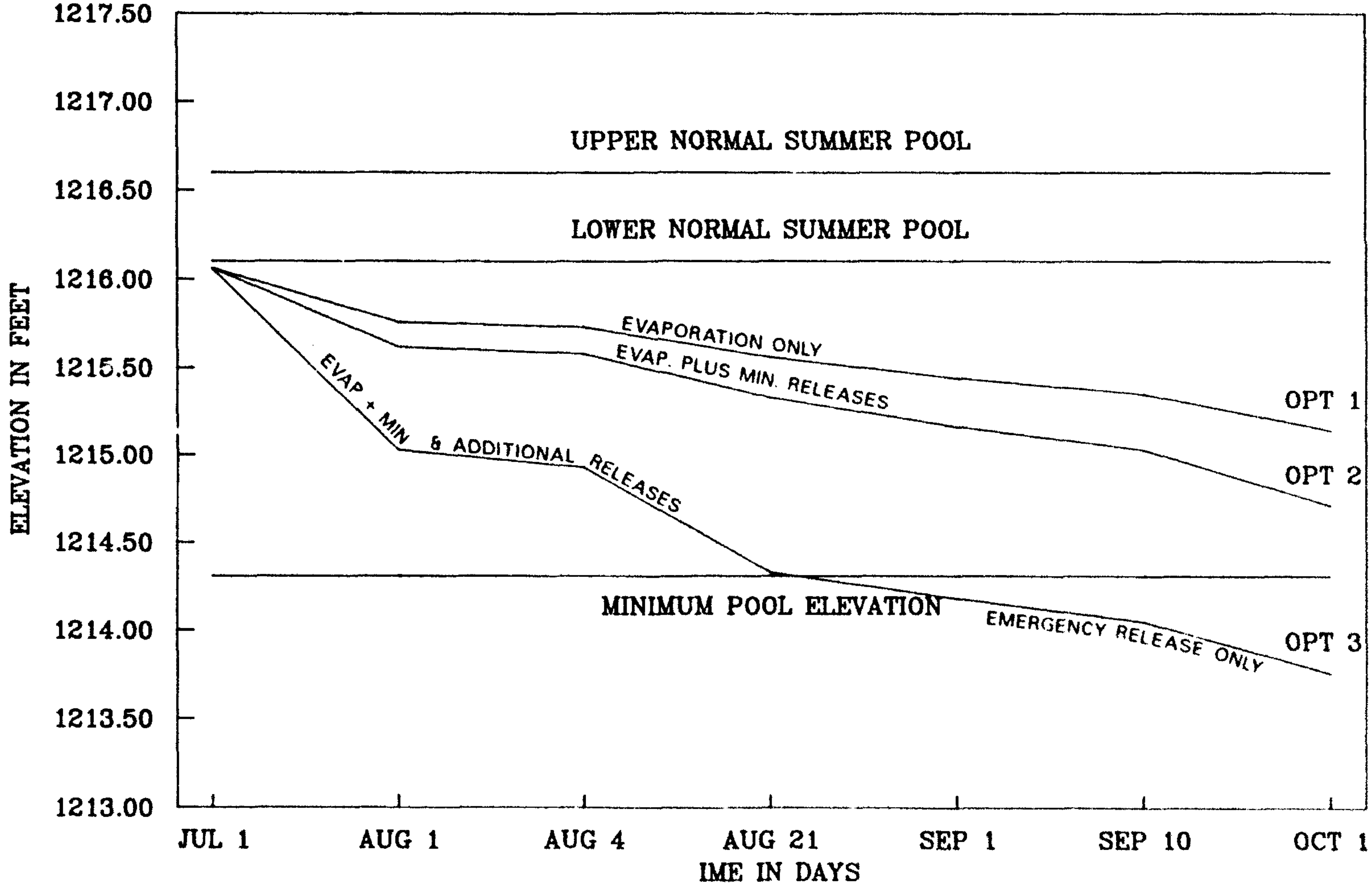
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 3

SANDY

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SC

SANDY LAKE

PERIOD FROM: JULY 1
TO: OCTOBER 1

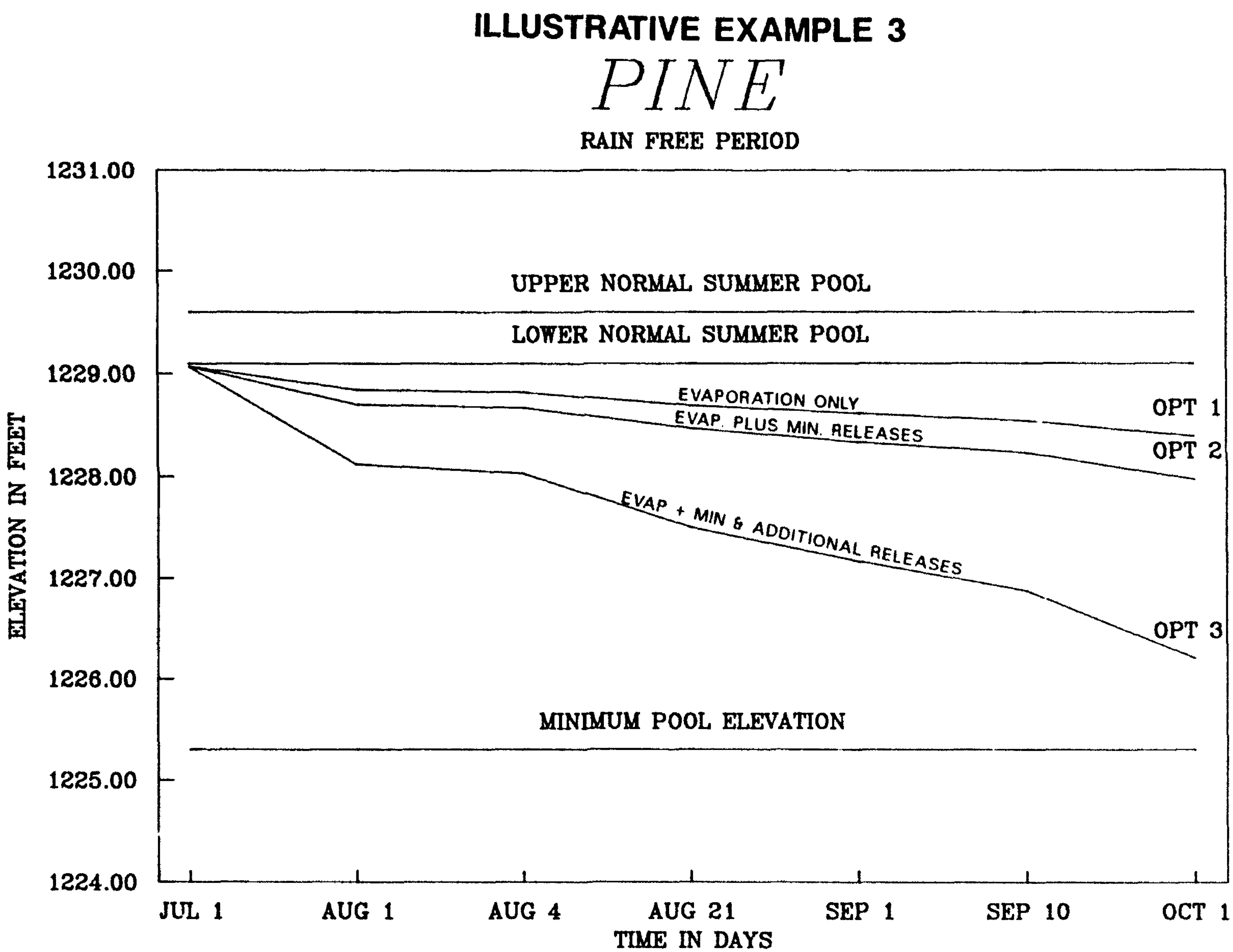
ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1216.06		
		-0.30	-0.30
AUGUST 1	1215.76		
		-0.03	-0.33
AUGUST 4	1215.73		
		-0.17	-0.50
AUGUST 21	1215.56		
		-0.12	-0.62
SEPTEMBER 1	1215.44		
		-0.09	-0.71
SEPTEMBER 10	1215.35		
		-0.21	-0.92
OCTOBER 1	1215.14		
OPTION 2: Evaporation plus minimum releases (20 cfs)			
JULY 1	1216.06		
		-0.44	-0.44
AUGUST 1	1215.62		
		-0.04	-0.48
AUGUST 4	1215.58		
		-0.25	-0.73
AUGUST 21	1215.33		
		-0.17	-0.90
SEPTEMBER 1	1215.16		
		-0.13	-1.03
SEPTEMBER 10	1215.03		
		-0.32	-1.35
OCTOBER 1	1214.71		
OPTION 3: Evaporation & min. releases & additional flows (84 cfs)			
JULY 1	1216.06		
		-1.03	-1.03
AUGUST 1	1215.03		
		-0.10	-1.13
AUGUST 4	1214.93		
		-0.60	-1.73
AUGUST 21	1214.33		
		-0.15	-1.88
SEPTEMBER 1	1214.18		
		-0.13	-2.01
SEPTEMBER 10	1214.05		
		-0.29	-2.30
OCTOBER 1	1213.76		

EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.



NOTE: X-AXIS NOT TO SCALE

PINE RIVER   PERIOD   FROM: JULY 1
TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1229.07		
		-0.23	-0.23
AUGUST 1	1228.84		
		-0.02	-0.25
AUGUST 4	1228.82		
		-0.13	-0.38
AUGUST 21	1228.69		
		-0.08	-0.46
SEPTEMBER 1	1228.61		
		-0.07	-0.53
SEPTEMBER 10	1228.54		
		-0.15	-0.68
OCTOBER 1	1228.39		
OPTION 2: Evaporation plus minimum releases (30 cfs)			
JULY 1	1229.07		
		-0.37	-0.37
AUGUST 1	1228.70		
		-0.03	-0.40
AUGUST 4	1228.67		
		-0.20	-0.60
AUGUST 21	1228.47		
		-0.14	-0.74
SEPTEMBER 1	1228.33		
		-0.10	-0.84
SEPTEMBER 10	1228.23		
		-0.26	-1.10
OCTOBER 1	1227.97		
OPTION 3: Evaporation & min. releases & additional flows (126 cfs)			
JULY 1	1229.07		
		-0.95	-0.95
AUGUST 1	1228.12		
		-0.09	-1.04
AUGUST 4	1228.03		
		-0.53	-1.57
AUGUST 21	1227.50		
		-0.34	-1.91
SEPTEMBER 1	1227.16		
		-0.29	-2.20
SEPTEMBER 10	1226.87		
		-0.67	-2.87
OCTOBER 1	1226.20		

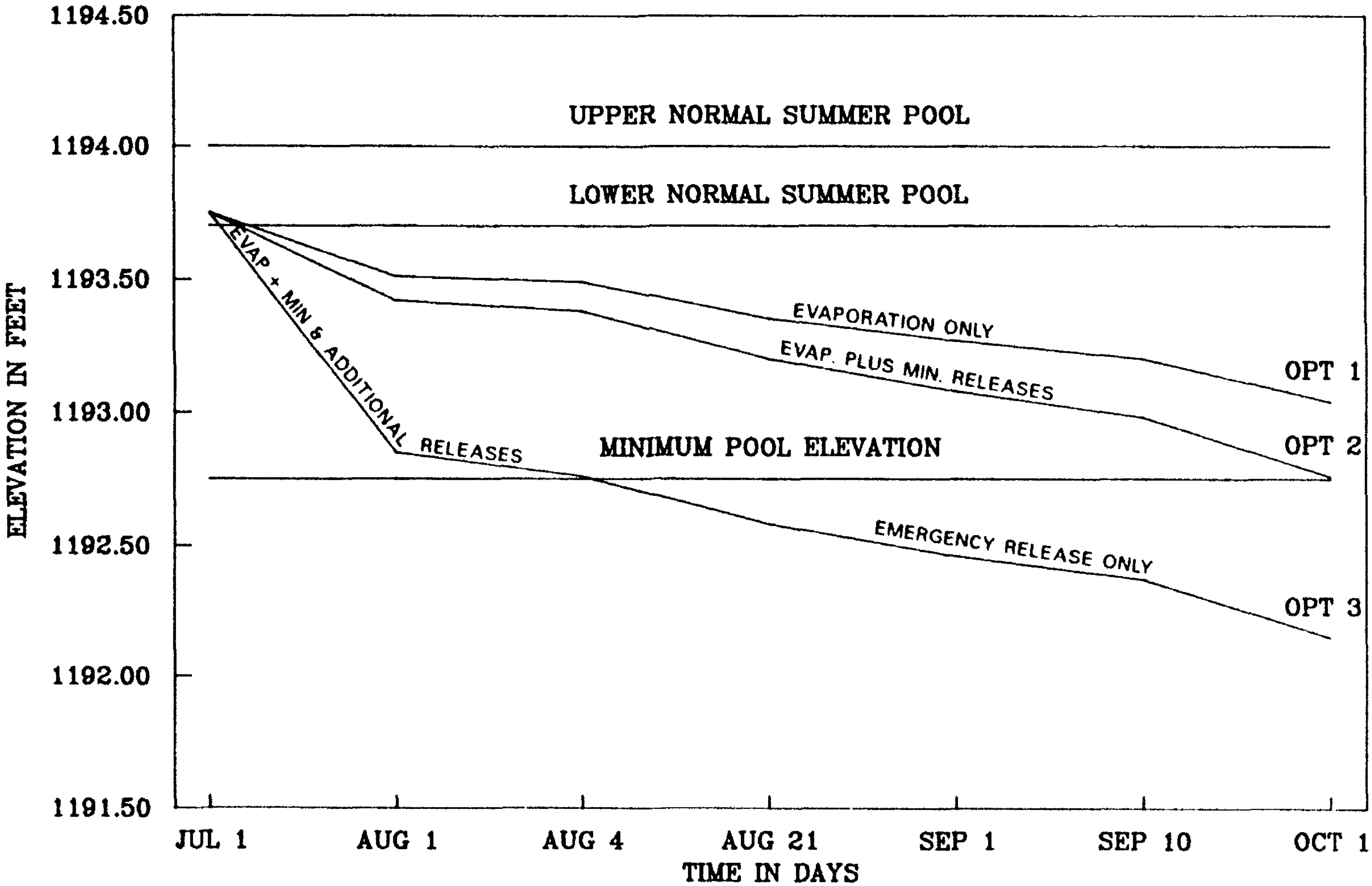
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

ILLUSTRATIVE EXAMPLE 3

GULL

RAIN FREE PERIOD



NOTE: X-AXIS NOT TO SCALE

GULL LAKE | PERIOD FROM: JULY 1 TO: OCTOBER 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	ELEV	INCREMENTAL CHANGES	SUMMATION OF CHANGES
OPTION 1: Evaporation only			
JULY 1	1193.75		
		-0.24	-0.24
AUGUST 1	1193.51		
		-0.02	-0.26
AUGUST 4	1193.49		
		-0.14	-0.40
AUGUST 21	1193.35		
		-0.08	-0.48
SEPTEMBER 1	1193.27		
		-0.07	-0.55
SEPTEMBER 10	1193.20		
		-0.16	-0.71
OCTOBER 1	1193.04		
OPTION 2: Evaporation plus minimum releases (20 cfs)			
JULY 1	1193.75		
		-0.33	-0.33
AUGUST 1	1193.42		
		-0.04	-0.37
AUGUST 4	1193.38		
		-0.18	-0.55
AUGUST 21	1193.20		
		-0.12	-0.67
SEPTEMBER 1	1193.08		
		-0.10	-0.77
SEPTEMBER 10	1192.98		
		-0.22	-0.99
OCTOBER 1	1192.76		
OPTION 3: Evaporation & min. releases & additional flows (120 cfs)			
JULY 1	1193.75		
		-0.90	-0.90
AUGUST 1	1192.85		
		-0.09	-0.99
AUGUST 4	1192.76		
		-0.18	-1.17
AUGUST 21	1192.58		
		-0.12	-1.29
SEPTEMBER 1	1192.46		
		-0.09	-1.38
SEPTEMBER 10	1192.37		
		-0.22	-1.60
OCTOBER 1	1192.15		

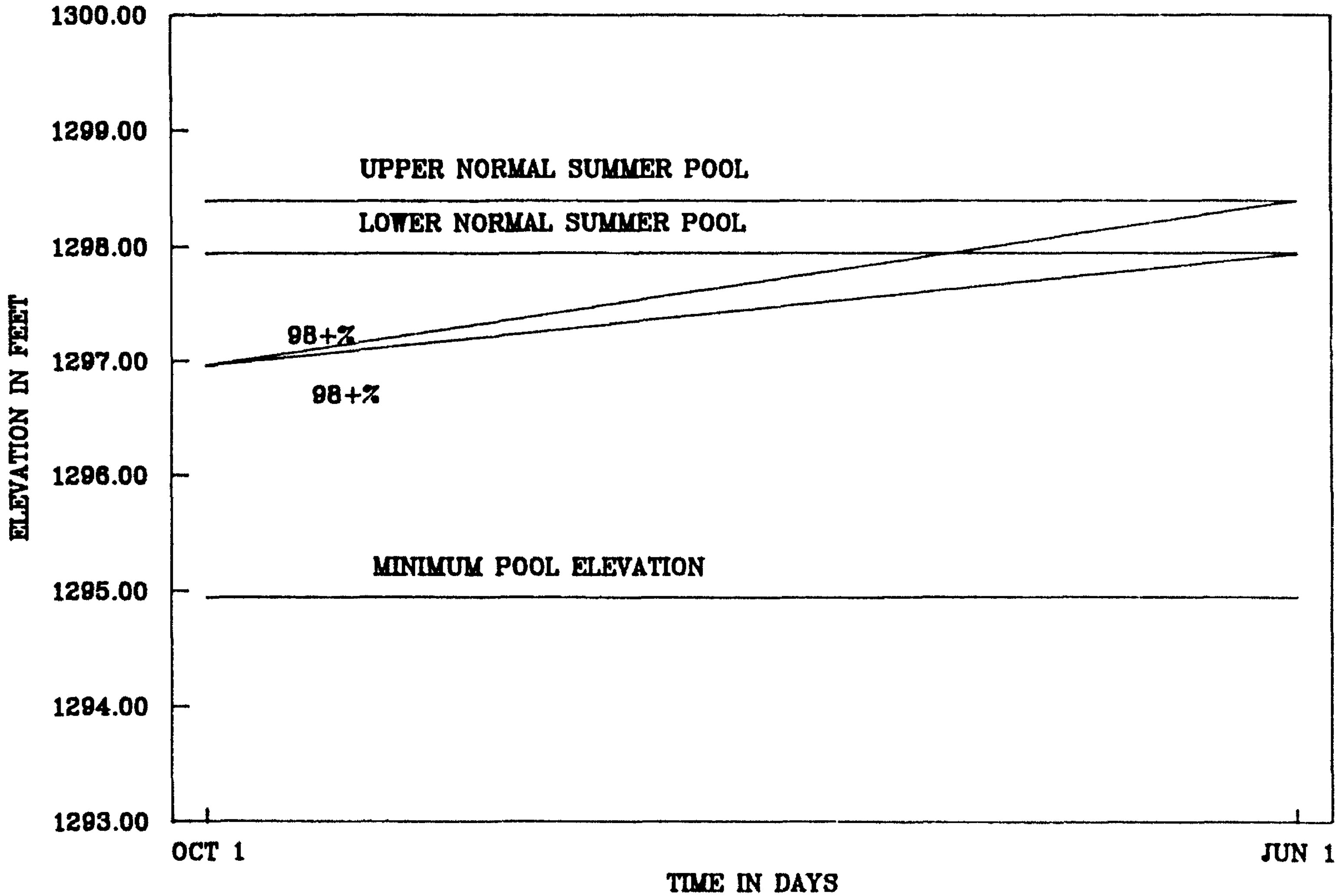
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

WINNIBIGOSHISH

OPTION 2: EVAPORATION + MINIMUM RELEASES



LAKE WINNIBIGOSHISH
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV - 1294.94
UPPER NORMAL SUMMER POOL - 1298.4
LOWER NORMAL SUMMER POOL - 1297.94

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1296.96	1296.96
JUNE 1	1297.94	1298.40
OPTION 3: Evaporation & min. releases & additional flows (90 cfs)		
OCTOBER 1	1296.69	1296.69
JUNE 1	1297.94	1298.40

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

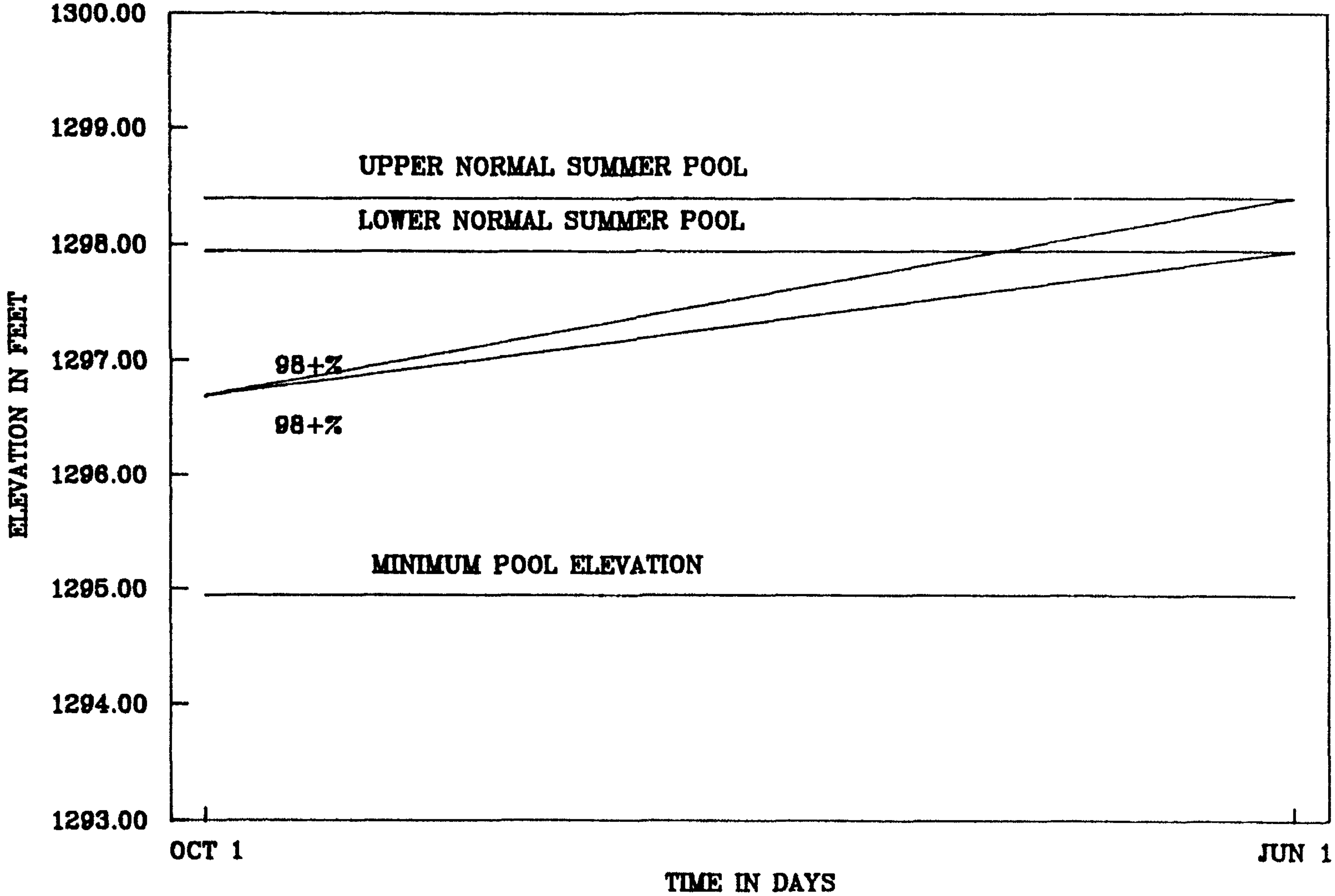
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

WINNIBIGOSHISH

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



LAKE WINNIBIGOSHISH
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1296.96	1296.96
JUNE 1	1297.94	1298.40
OPTION 3: Evaporation & min. releases & additional flows (90 cfs)		
OCTOBER 1	1296.69	1296.69
JUNE 1	1297.94	1298.40

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

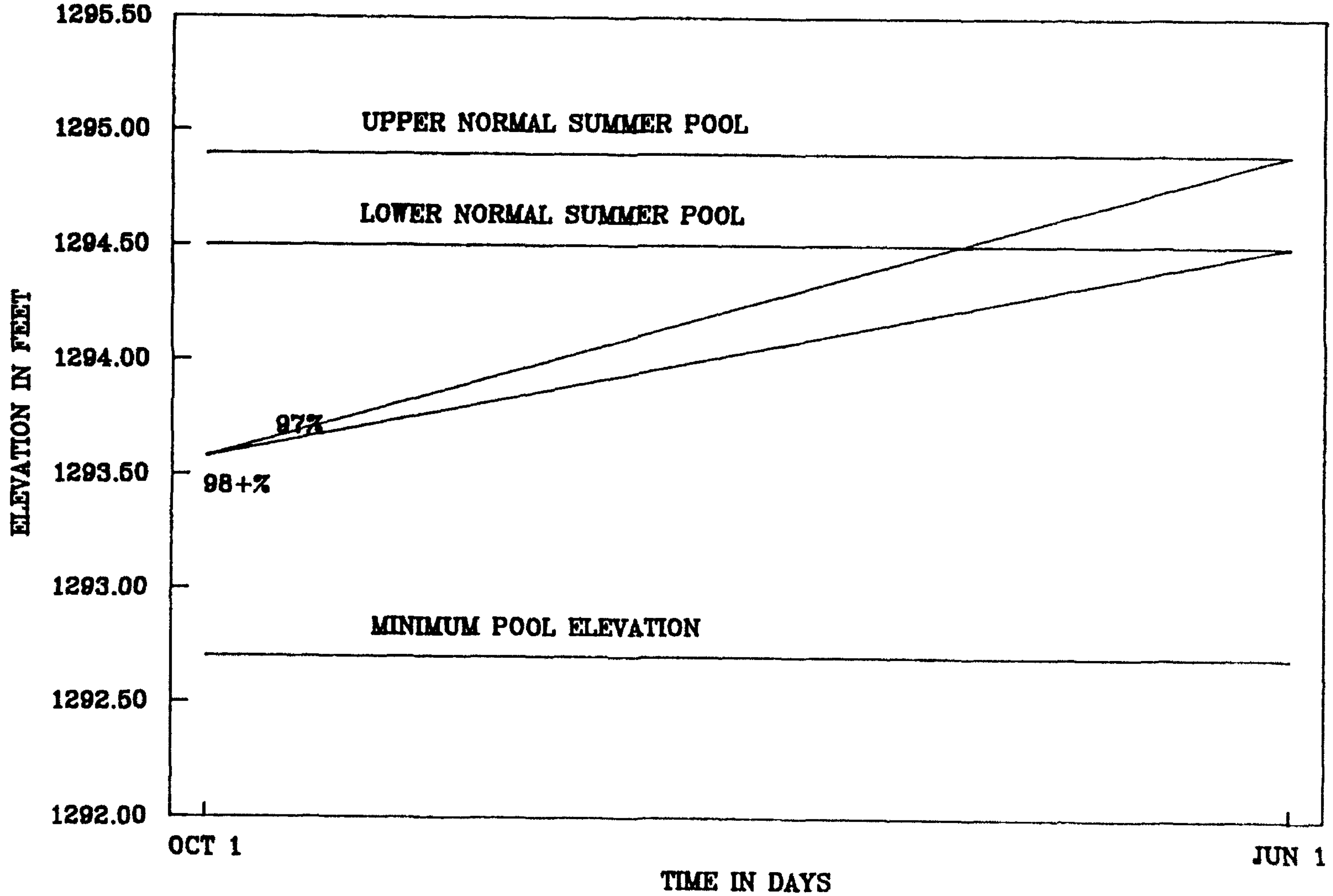
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

LEECH

OPTION 2: EVAPORATION + MINIMUM RELEASES



LEECH LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV - 1292.70
UPPER NORMAL SUMMER POOL - 1294.9
LOWER NORMAL SUMMER POOL - 1294.50

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	97% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1293.58	1293.58
JUNE 1	1294.50	1294.90

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	90% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 3: Evaporation & min. releases & additional flows (174 cfs)		
OCTOBER 1	1293.29	1293.29
JUNE 1	1294.50	1294.90

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

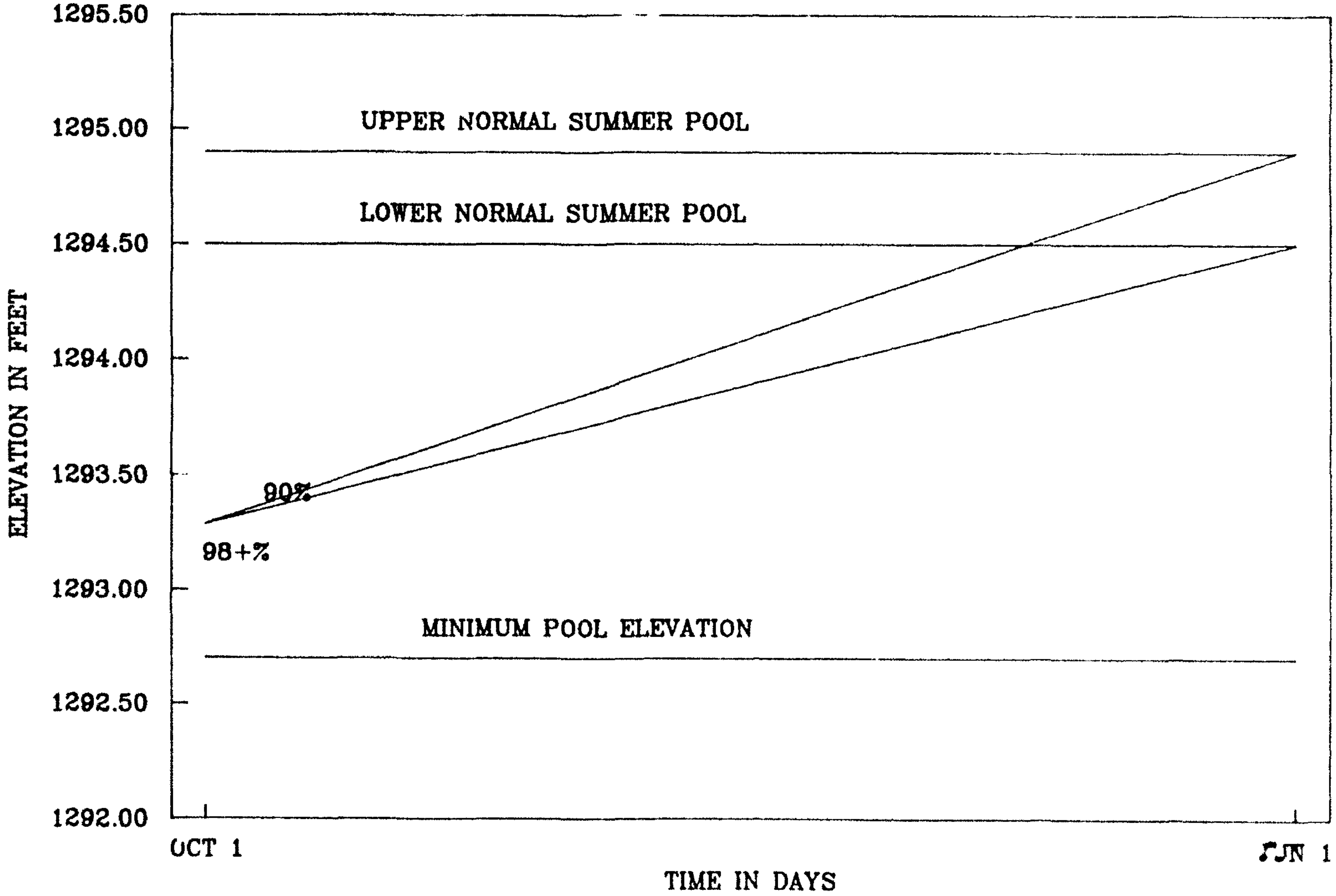
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

LEECH

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



LEECH LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1292.70
UPPER NORMAL SUMMER POOL = 1294.9
LOWER NORMAL SUMMER POOL = 1294.50

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	97% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1293.58	1293.58
JUNE 1	1294.50	1294.90

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	90% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 3: Evaporation & min. releases & additional flows (174 cfs)		
OCTOBER 1	1293.29	1293.29
JUNE 1	1294.50	1294.90

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

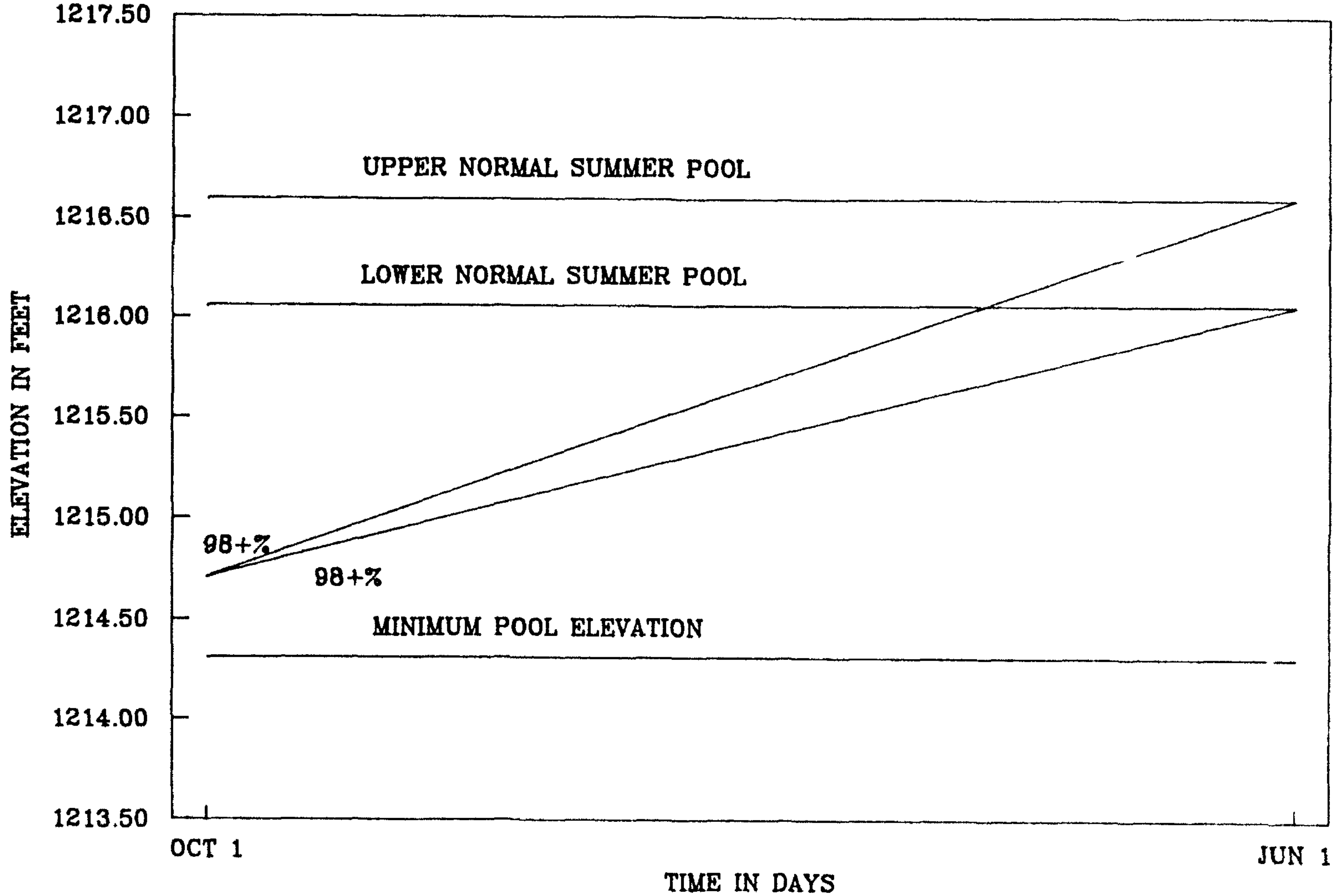
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

SANDY

OPTION 2: EVAPORATION + MINIMUM RELEASES



SANDY LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV - 1214.31
UPPER NORMAL SUMMER POOL - 1216.6
LOWER NORMAL SUMMER POOL - 1216.06

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1214.71	1214.71
JUNE 1	1216.06	1216.60
OPTION 3: Evaporation & min. releases & additional flows (12 cfs)		
OCTOBER 1	1214.45	1214.45
JUNE 1	1216.06	1216.60

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

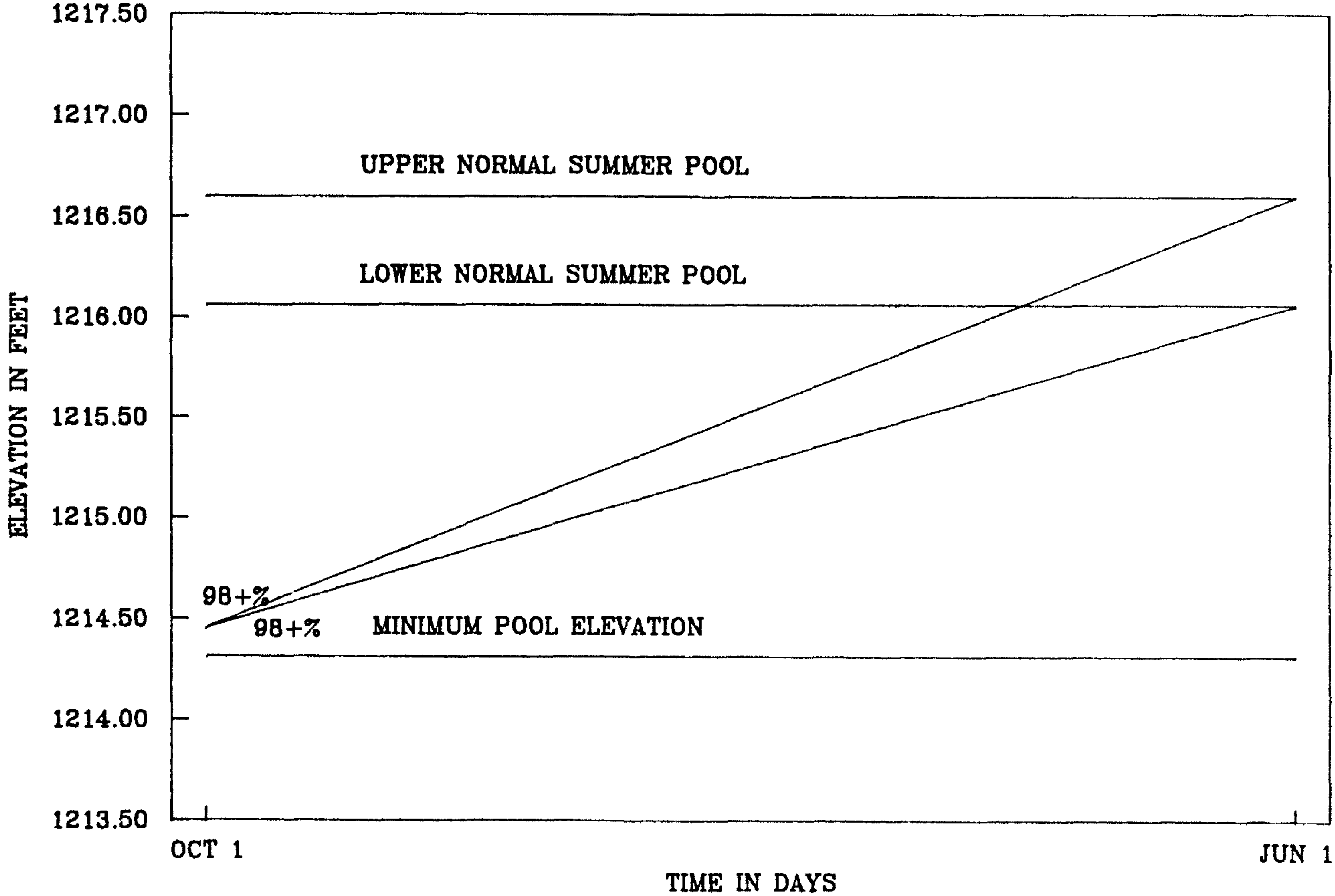
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

SANDY

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



SANDY LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	98+% RECOVER-ABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVER-ABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1214.71	1214.71
JUNE 1	1216.06	1216.60
OPTION 3: Evaporation & min. releases & additional flows (12 cfs)		
OCTOBER 1	1214.45	1214.45
JUNE 1	1216.06	1216.60

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

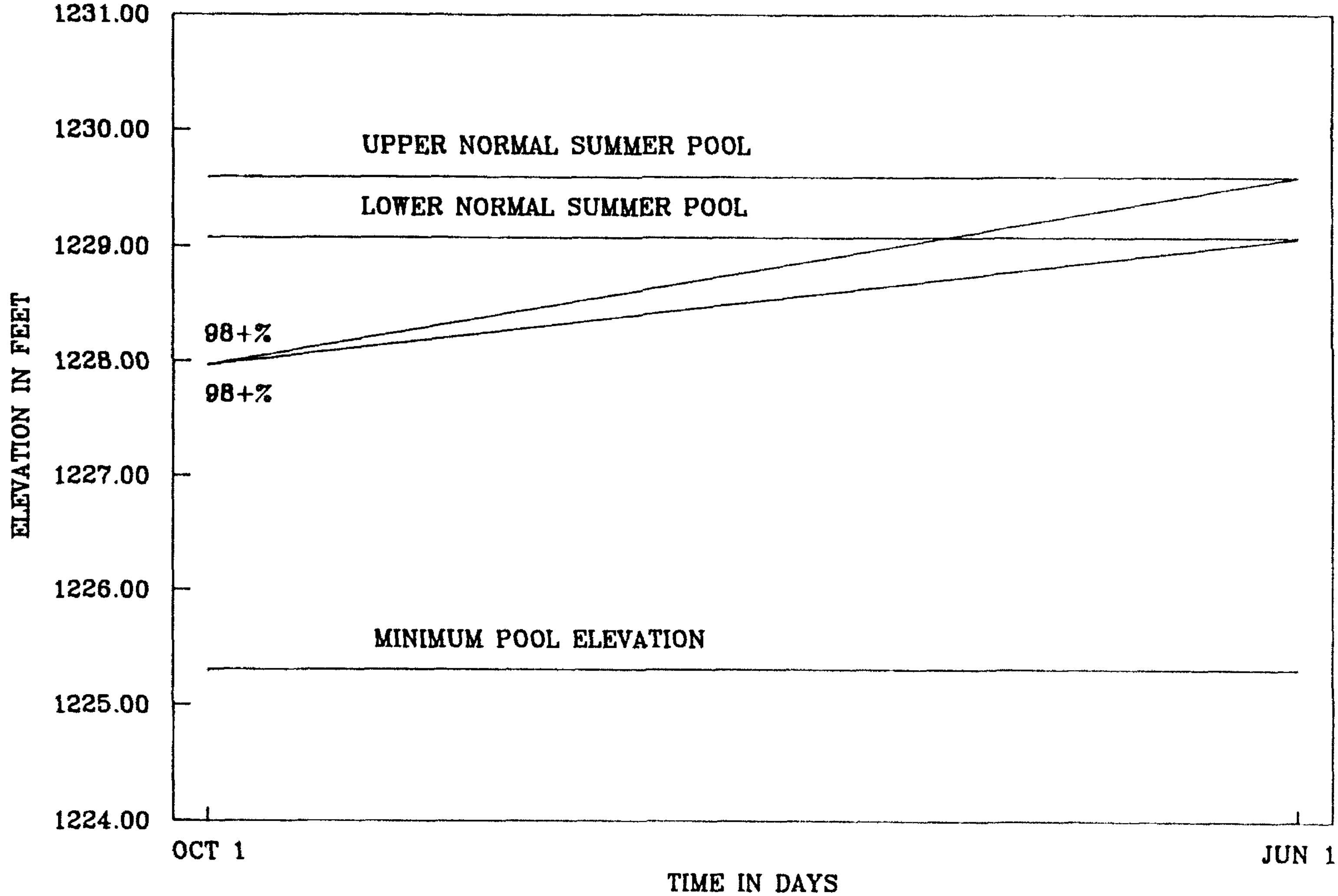
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

PINE

OPTION 2: EVAPORATION + MINIMUM RELEASES



PINE RIVER
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV - 1225.32
UPPER NORMAL SUMMER POOL - 1229.6
LOWER NORMAL SUMMER POOL - 1229.07

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (30 cfs)		
OCTOBER 1	1227.97	1227.97
JUNE 1	1229.07	1229.6
OPTION 3: Evaporation & min. releases & additional flows (18 cfs)		
OCTOBER 1	1227.72	1227.72
JUNE 1	1229.07	1229.6

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

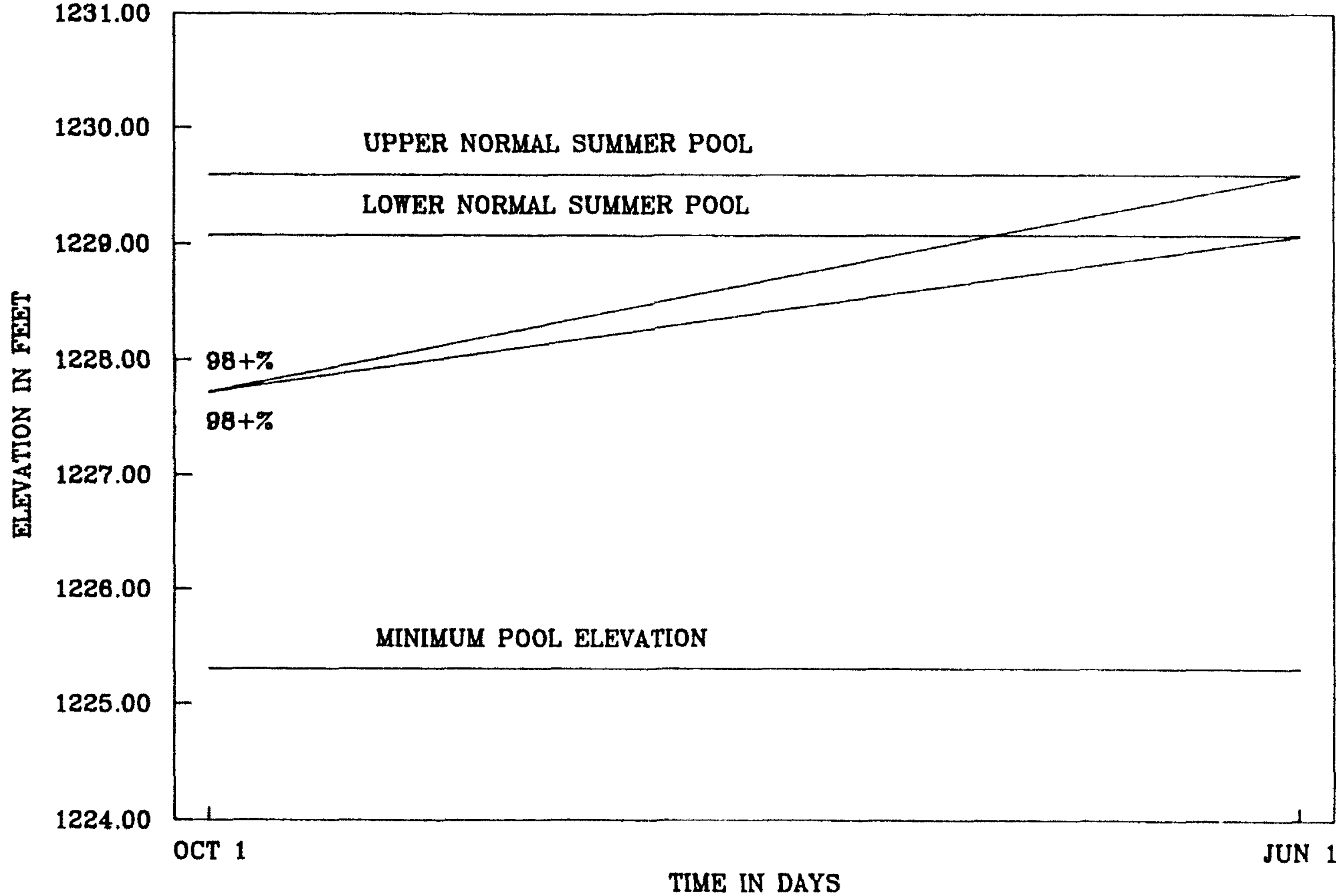
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

PINE

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



PINE RIVER
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	98+% RECOVER-ABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVER-ABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (30 cfs)		
OCTOBER 1	1227.97	1227.97
JUNE 1	1229.07	1229.6
OPTION 3: Evaporation & min. releases & additional flows (18 cfs)		
OCTOBER 1	1227.72	1227.72
JUNE 1	1229.07	1229.6

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

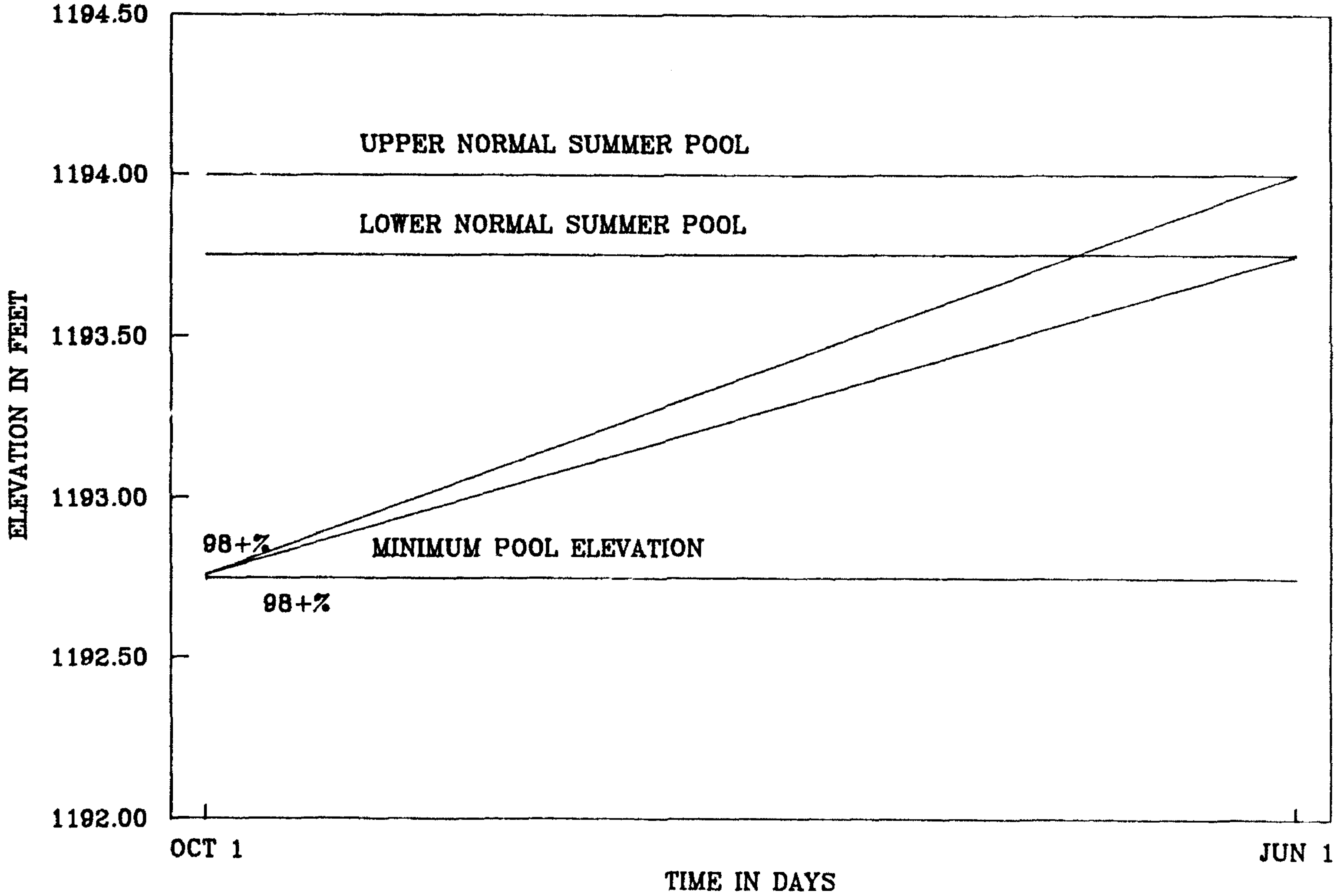
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

GULL

OPTION 2: EVAPORATION + MINIMUM RELEASES



GULL LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS. SUMMER BANDS. WINNI, LEECH, & POKE

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1192.76	1192.76
JUNE 1	1193.75	1194.00
OPTION 3: Evaporation & min. releases & additional flows (16 cfs --minimum pool elevation reached on September 14, min. releases cut by 1/2, no additional releases made.)		
OCTOBER 1	1192.58	1192.58
JUNE 1	1193.75	1194.00

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

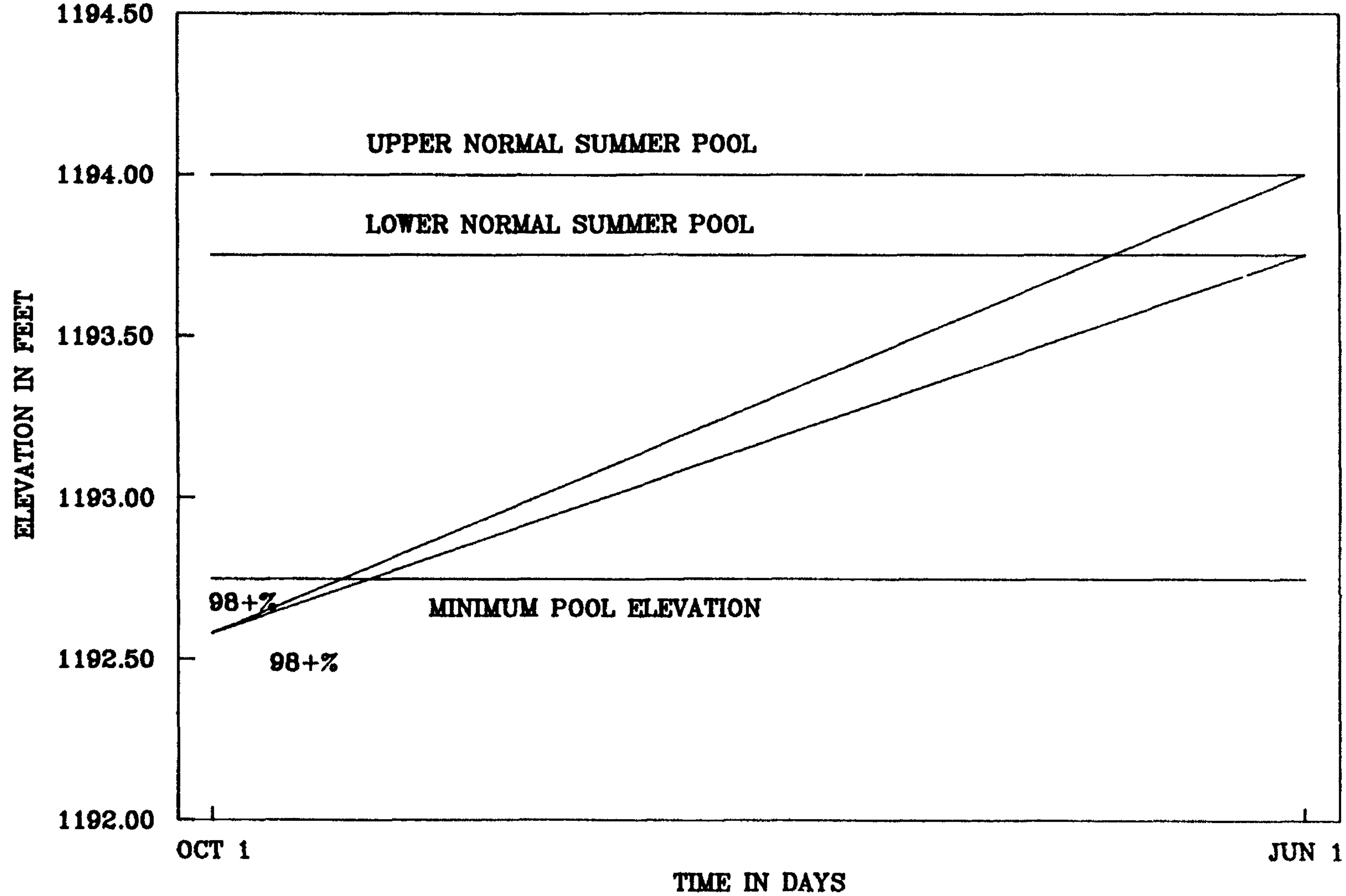
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 1

GULL

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



GULL LAKE
RECOVERABILITY — PERIOD FROM: OCTOBER 1 TO: JUNE 1

ILLUSTRATIVE EXAMPLE 1: ALL LAKES ARE AT THE BOTTOM OF THEIR SUMMER OPERATING BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE FOR ALL RESERVOIRS. SUMMER BANDS. WINNI, LEECH, & POKE

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1192.76	1192.76
JUNE 1	1193.75	1194.00
OPTION 3: Evaporation & min. releases & additional flows (16 cfs --minimum pool elevation reached on September 14, min. releases cut by 1/2, no additional releases made.)		
OCTOBER 1	1192.58	1192.58
JUNE 1	1193.75	1194.00

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

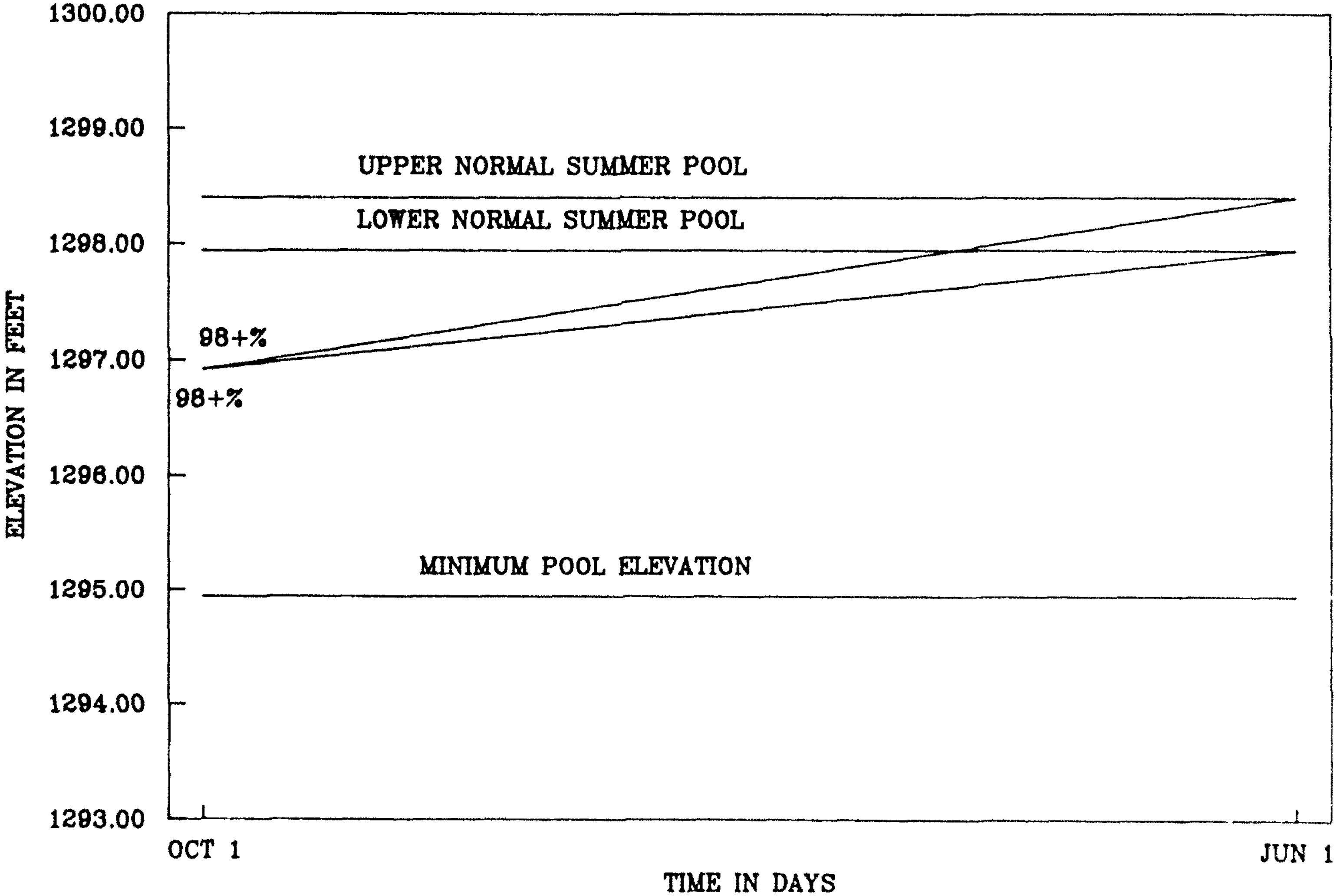
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

WINNIBIGOSHISH

OPTION 2: EVAPORATION + MINIMUM RELEASES



LAKE WINNIBIGOSHISH
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs + 10 cfs from Gull after July 1, + 10 cfs from Sandy after August 18).		
OCTOBER 1	1296.92	1296.92
JUNE 1	1297.94	1298.40
OPTION 3: Evaporation & min. releases & additional flows (105 cfs)		
OCTOBER 1	1296.61	1296.61
JUNE 1	1297.94	1298.40

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

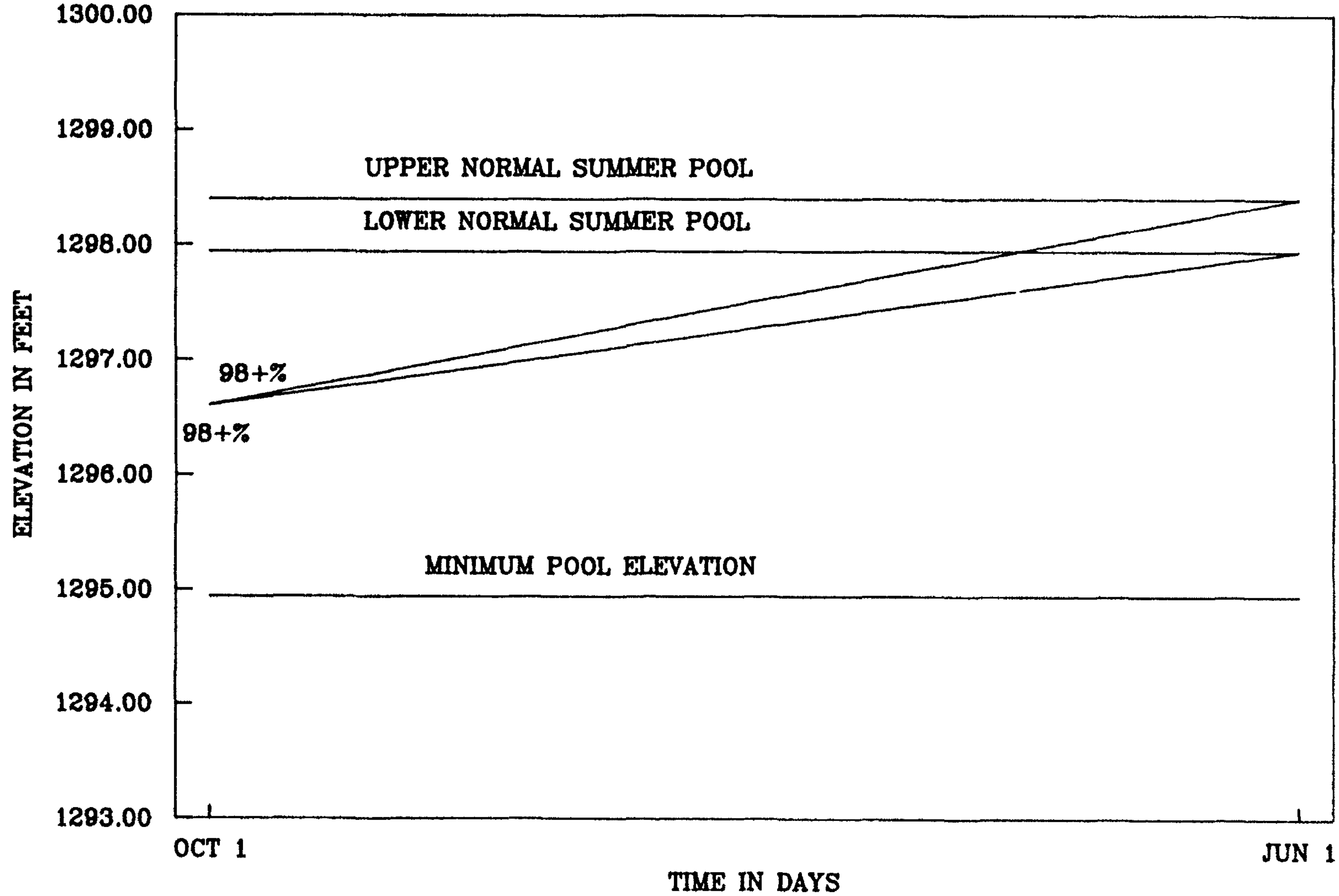
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

WINNIBIGOSHISH

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



LAKE WINNIBIGOSHISH
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs + 10 cfs from Gull after July 1, + 10 cfs from Sandy after August 18).		
OCTOBER 1	1296.92	1296.92
JUNE 1	1297.94	1298.40
OPTION 3: Evaporation & min. releases & additional flows (105 cfs)		
OCTOBER 1	1296.61	1296.61
JUNE 1	1297.94	1298.40

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

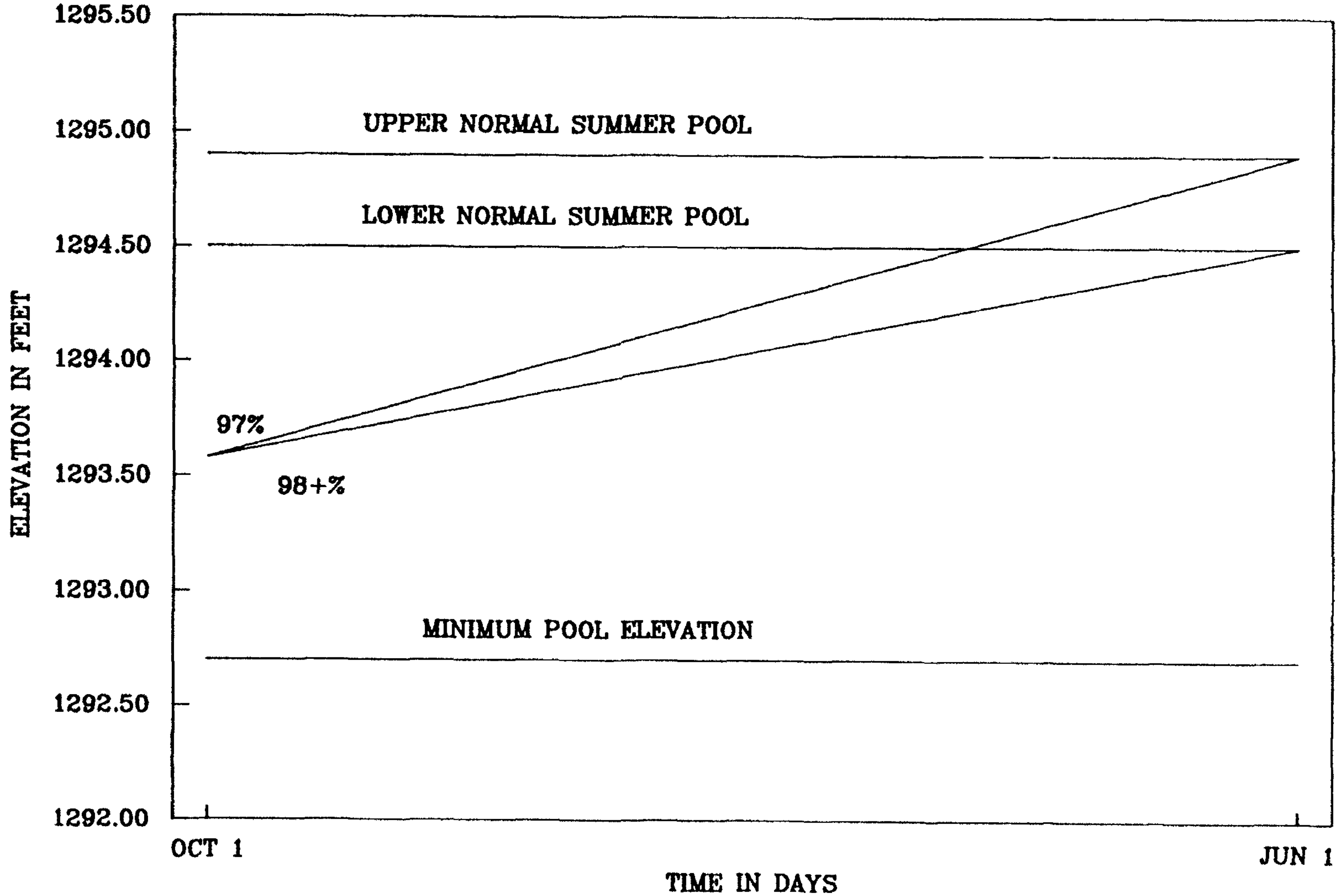
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

LEECH

OPTION 2: EVAPORATION + MINIMUM RELEASES



LEECH LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV - 1292.70
UPPER NORMAL SUMMER POOL - 1294.9
LOWER NORMAL SUMMER POOL - 1294.50

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	97% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1293.58	1293.58
JUNE 1	1294.50	1294.90

DATE	96% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	84% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 3: Evaporation & min. releases & additional flows (205 cfs)		
OCTOBER 1	1293.23	1293.23
JUNE 1	1294.50	1294.90

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

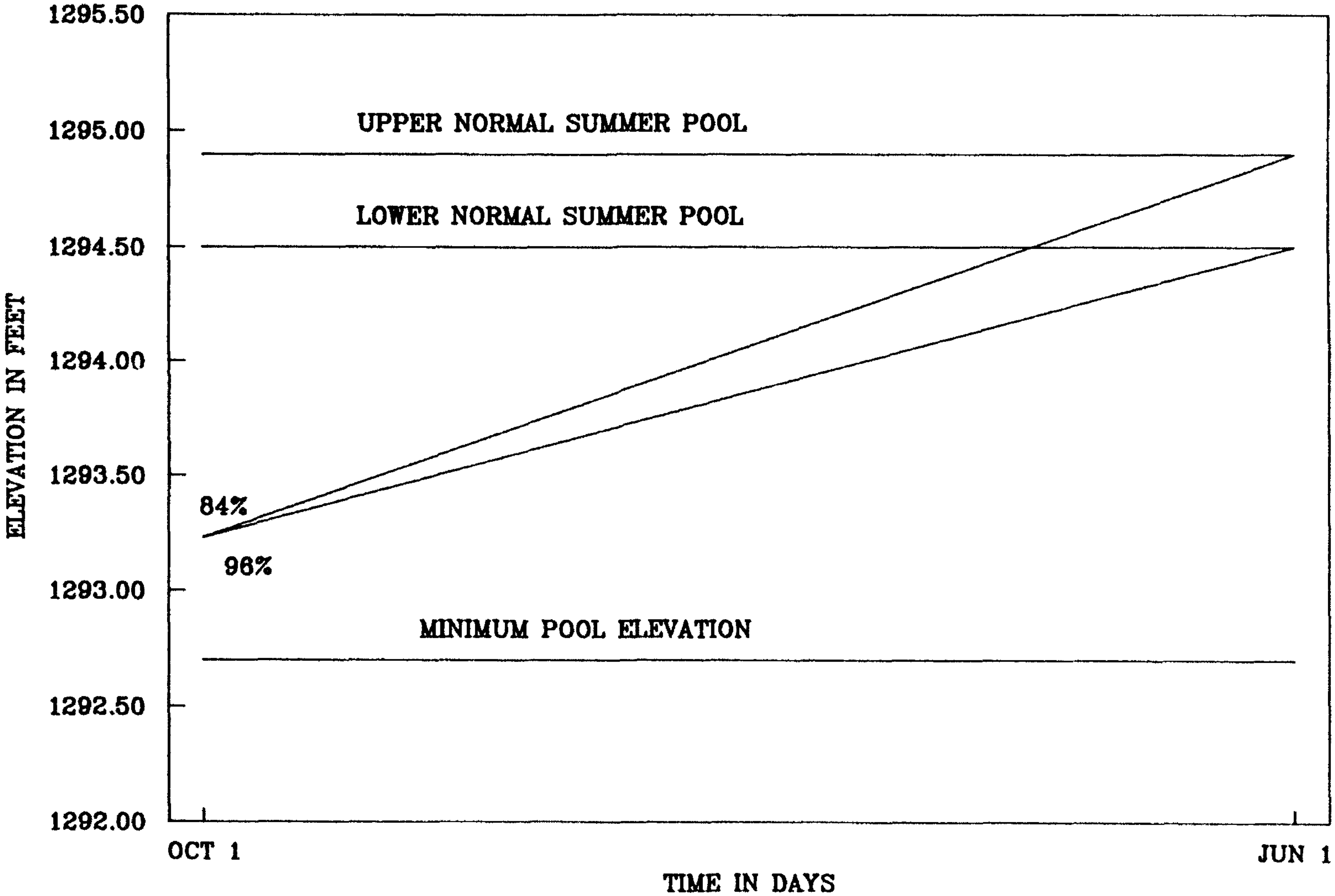
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

LEECH

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



LEECH LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1292.70
UPPER NORMAL SUMMER POOL = 1294.9
LOWER NORMAL SUMMER POOL = 1294.50

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	97% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1293.58	1293.58
JUNE 1	1294.50	1294.90

DATE	96% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	84% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 3: Evaporation & min. releases & additional flows (205 cfs)		
OCTOBER 1	1293.23	1293.23
JUNE 1	1294.50	1294.90

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

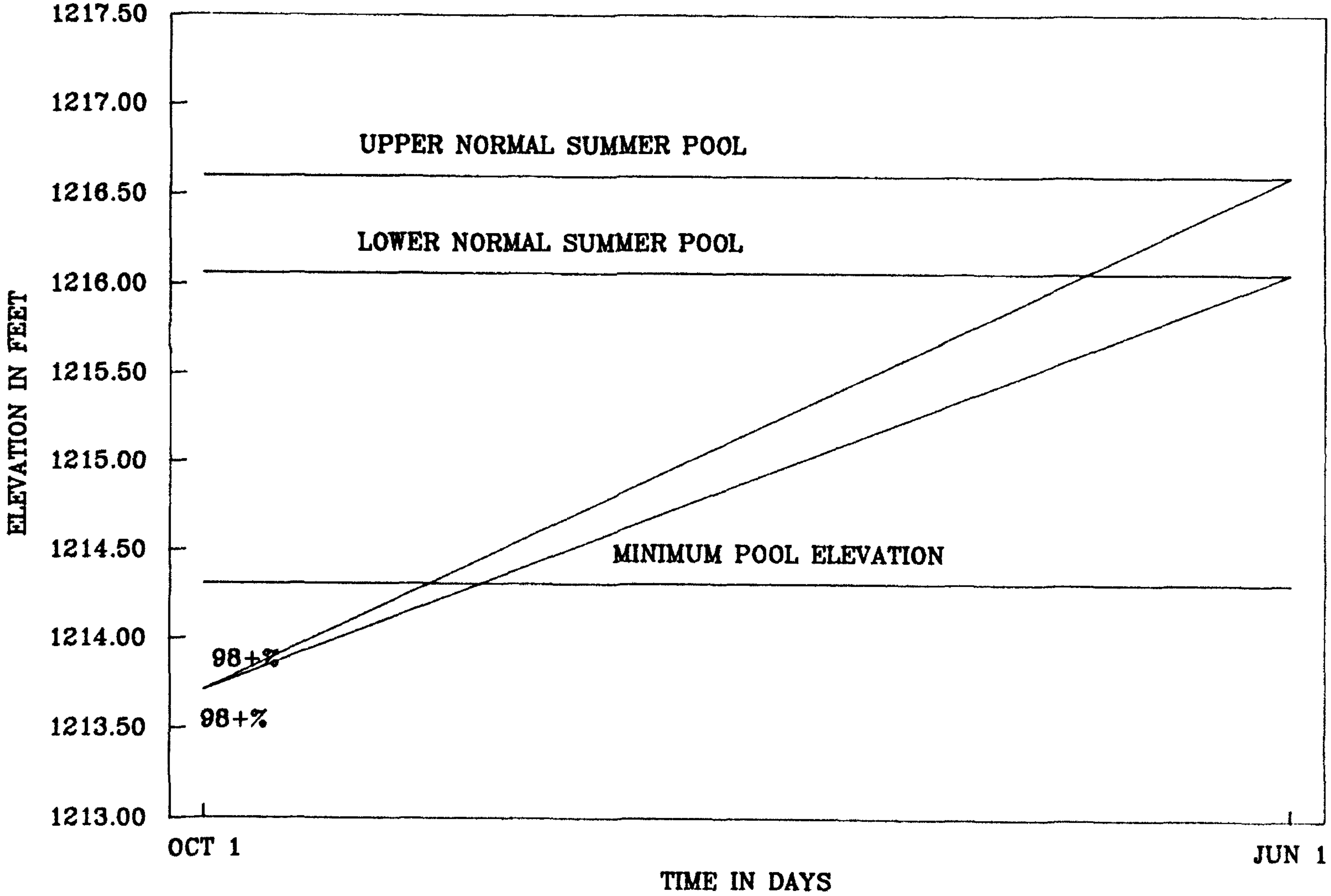
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

SANDY

OPTION 2: EVAPORATION + MINIMUM RELEASES



SANDY LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1213.71	1213.71
JUNE 1	1216.06	1216.60
OPTION 3: Evaporation & min. releases & additional flows (none)		
OCTOBER 1	1213.71	1213.71
JUNE 1	1216.06	1216.60

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

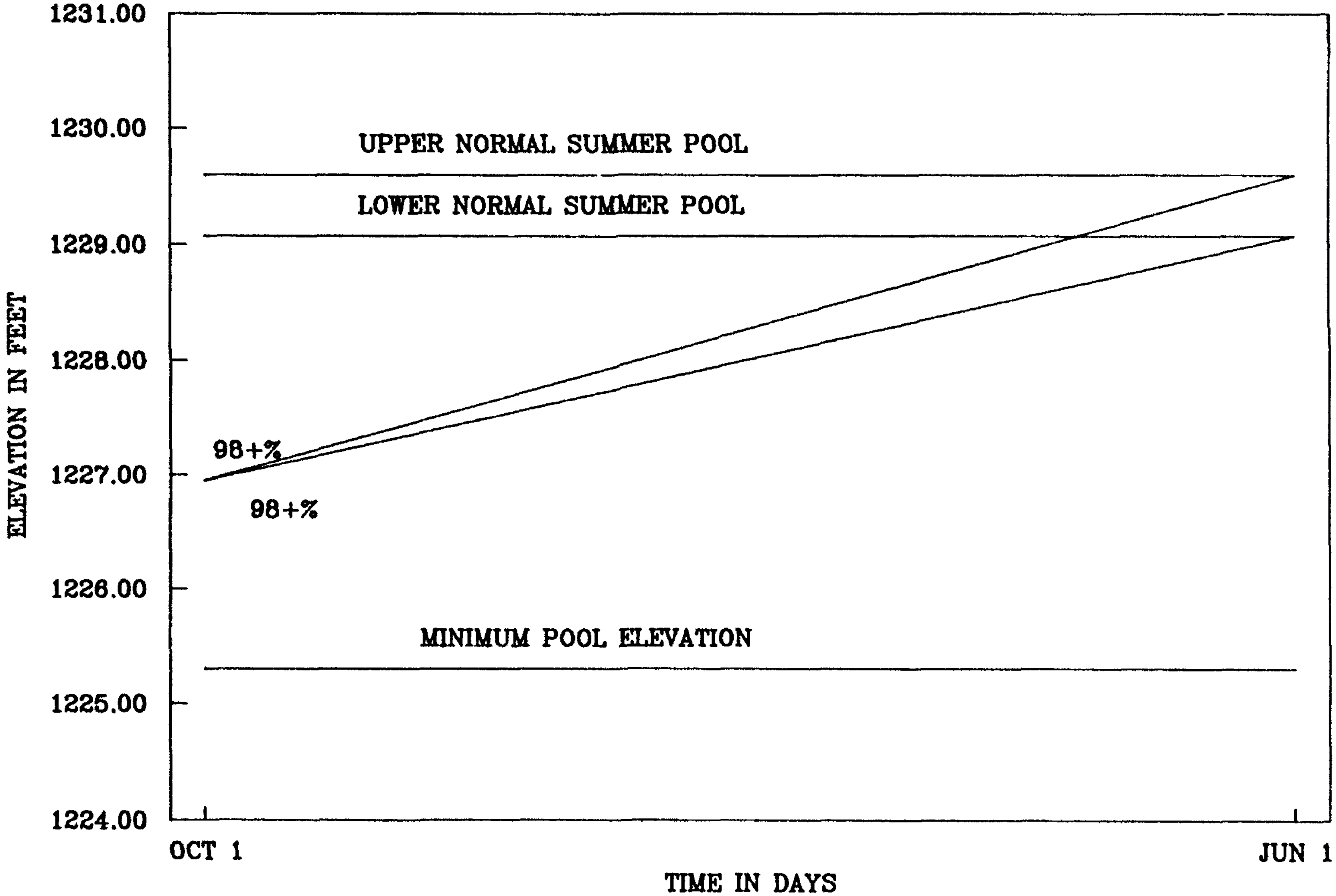
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

PINE

OPTION 2: EVAPORATION + MINIMUM RELEASES



PINE RIVER
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (30 cfs)		
OCTOBER 1	1226.95	1226.95
JUNE 1	1229.07	1229.6
OPTION 3: Evaporation & min. releases & additional flows (none)		
OCTOBER 1	1226.95	1226.95
JUNE 1	1229.07	1229.6

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

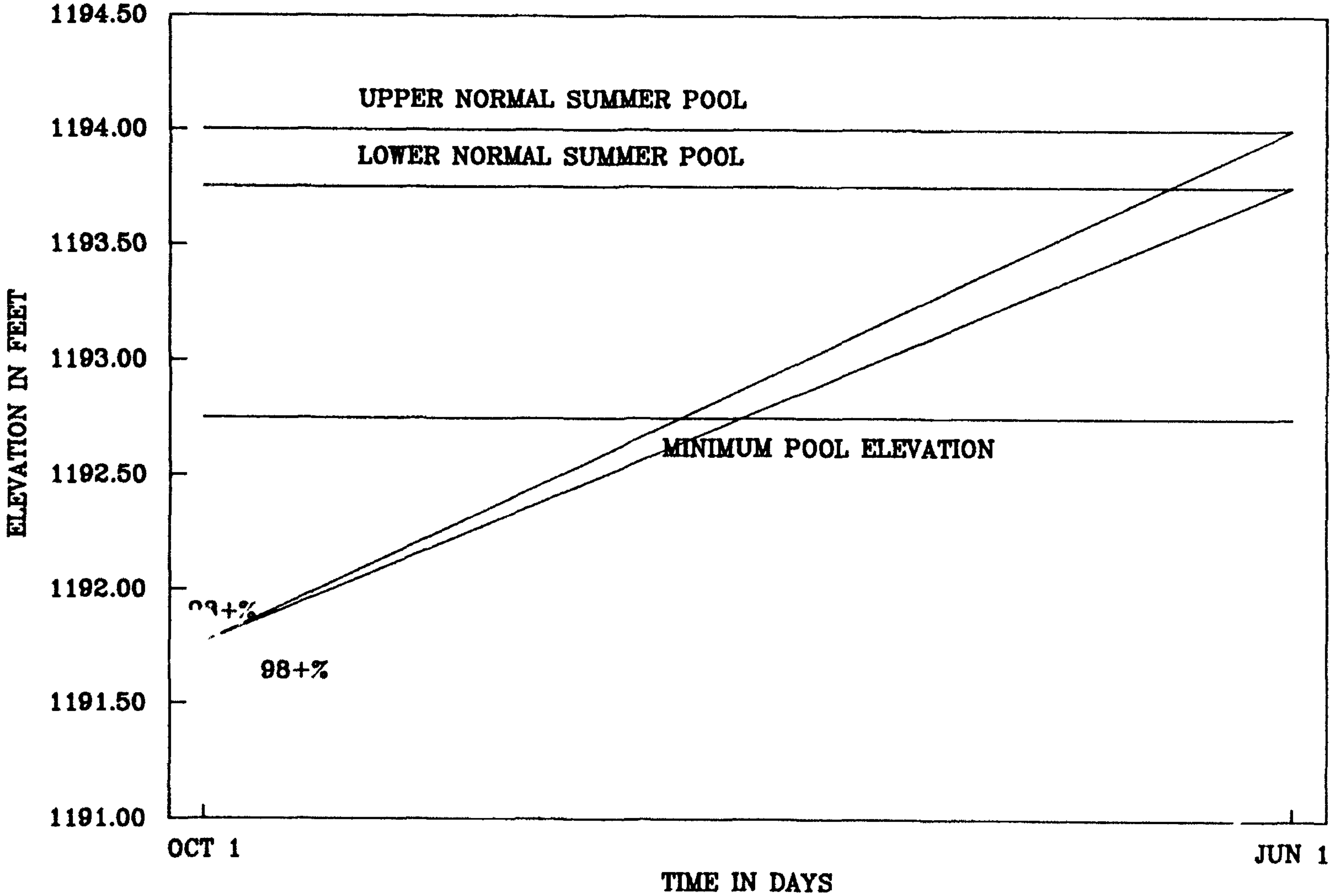
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 2

GULL

OPTION 2: EVAPORATION + MINIMUM RELEASES



GULL LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 2: WINNIBIGOSHISH, LEECH, & POKE ARE AT BOTTOM OF SUMMER BANDS. SANDY, PINE, & GULL ARE 1 FOOT BELOW SUMMER BANDS. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF WINNI, LEECH, & POKE. NO SUPPLEMENTAL RELEASES FOR SANDY, PINE & GULL.

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs--minimum pool elevation reached on Jul 1, releases cut by 1/2)		
OCTOBER 1	1191.77	1191.77
JUNE 1	1193.75	1194.00
OPTION 3: Evaporation & min. releases & additional flows (none)		
OCTOBER 1	1191.77	1191.77
JUNE 1	1193.75	1194.00

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

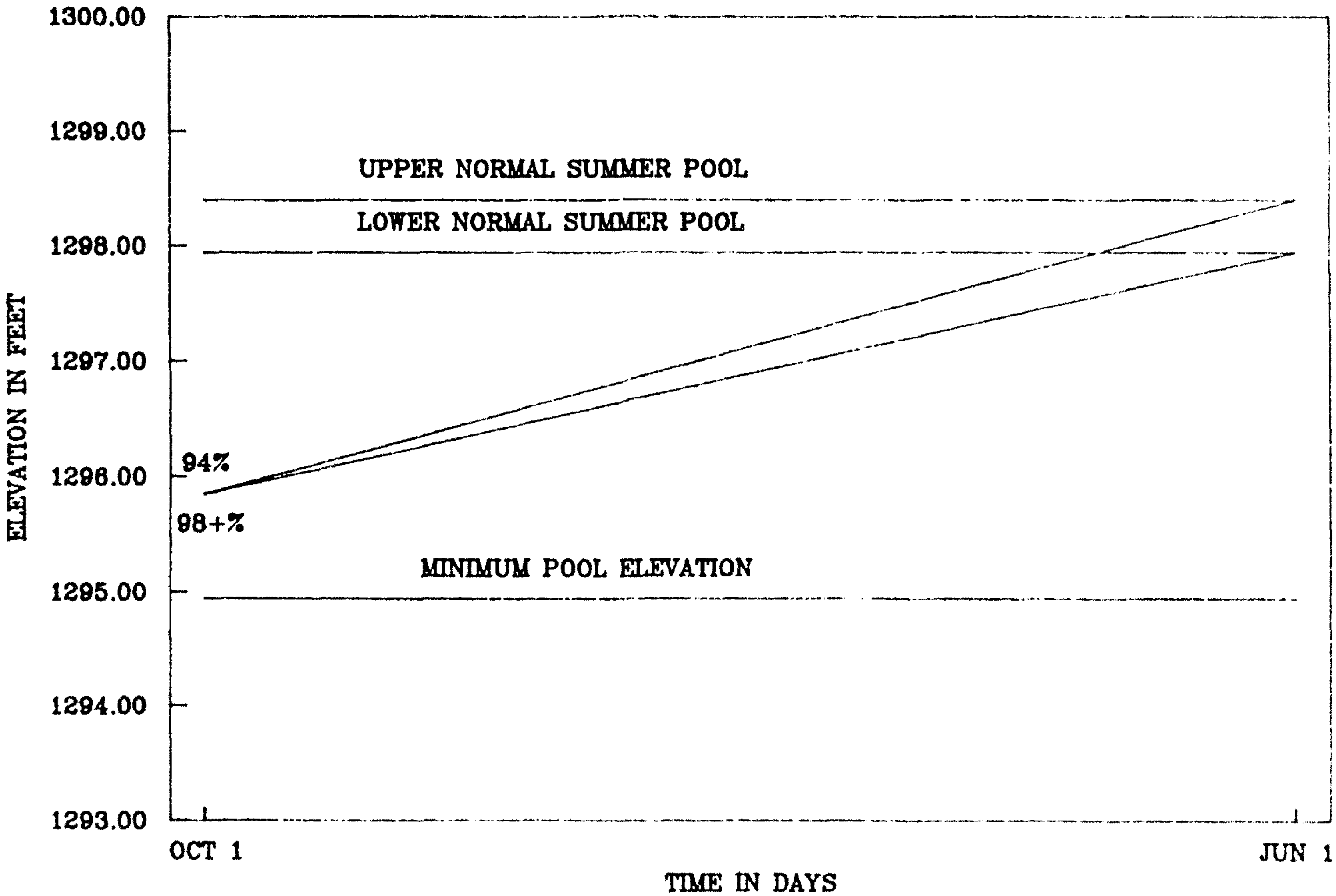
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

WINNIBIGOSHISH

OPTION 2: EVAPORATION + MINIMUM RELEASES



LAKE WINNIBIGOSHISH
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1294.94
UPPER NORMAL SUMMER POOL = 1298.4
LOWER NORMAL SUMMER POOL = 1297.94

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	94% RECOVERABILIT. TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1295.85	1295.85
JUNE 1	1297.94	1298.40

OPTION 3: Evaporation & min. releases & additional flows (+ 130 cfs from Gull after Aug 4, +94 cfs from Sandy after Aug 21).

DATE	96% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	90% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OCTOBER 1	1295.46	1295.46
JUNE 1	1297.94	1298.40

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS .E STARTING ELEVATION VARIES.

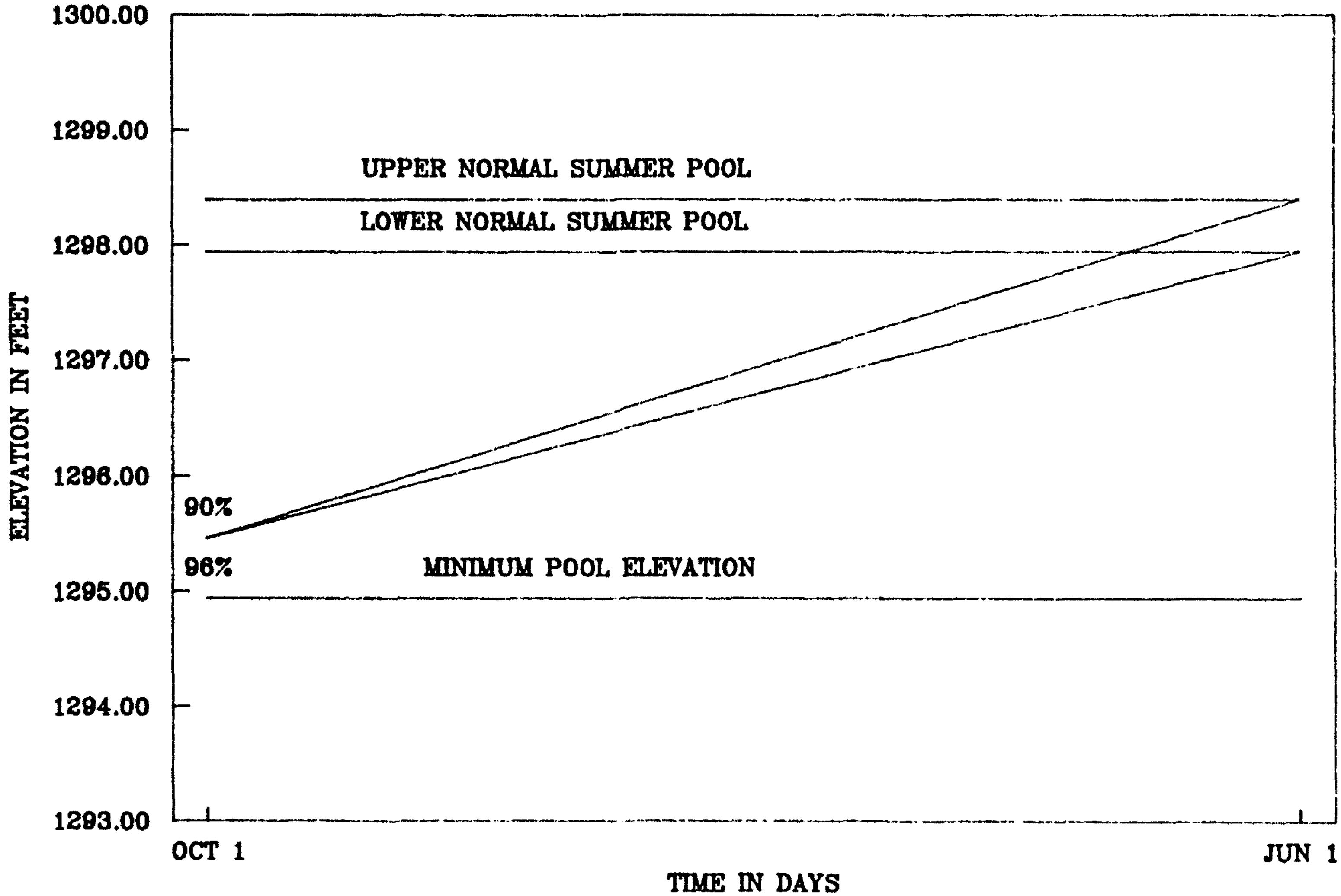
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

WINNIBIGOSHISH

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



LAKE WINNIBIGOSHISH
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV - 1294.94
UPPER NORMAL SUMMER POOL - 1298.4
LOWER NORMAL SUMMER POOL - 1297.94

OPTION 2: Evaporation plus minimum releases (100 cfs)

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	94% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OCTOBER 1	1295.85	1295.85
JUNE 1	1297.94	1298.40

OPTION 3: Evaporation & min. releases & additional flows (+ 130 cfs from Gull after Aug 4, +94 cfs from Sandy after Aug 21).

DATE	96% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	90% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OCTOBER 1	1295.46	1295.46
JUNE 1	1297.94	1298.40

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

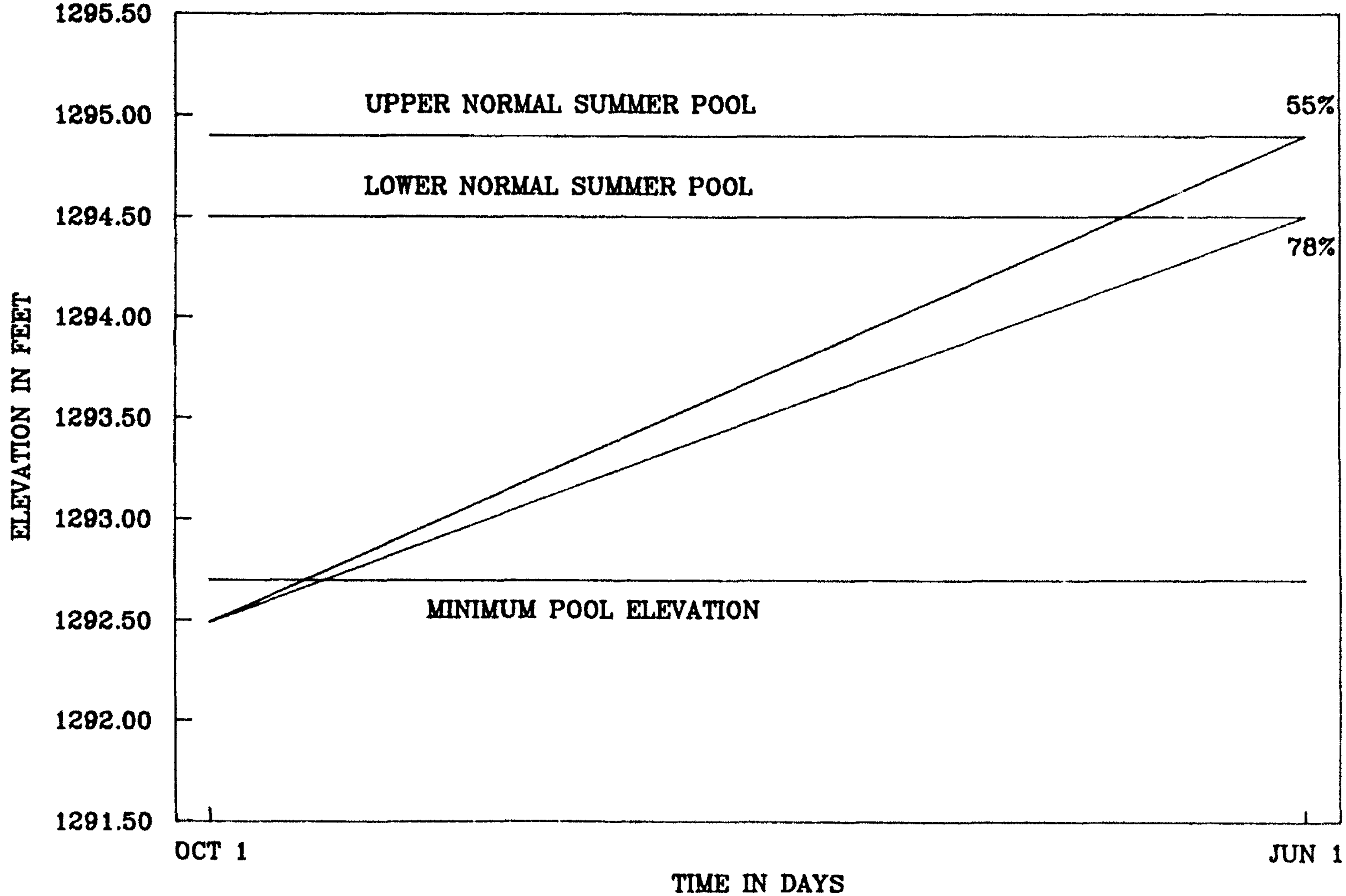
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

LEECH

OPTION 2: EVAPORATION + MINIMUM RELEASES



LEECH LAKE
RECOVERABILITY — PERIOD FROM: OCTOBER 1 TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1292.70
UPPER NORMAL SUMMER POOL = 1294.9
LOWER NORMAL SUMMER POOL = 1294.50

DATE	78% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	55% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (100 cfs)		
OCTOBER 1	1292.49	1292.49
JUNE 1	1294.50	1294.90

DATE	78% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	55% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 3: Evaporation & min. releases & additional flows (none)		
OCTOBER 1	1292.49	1292.49
JUNE 1	1294.50	1294.90

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

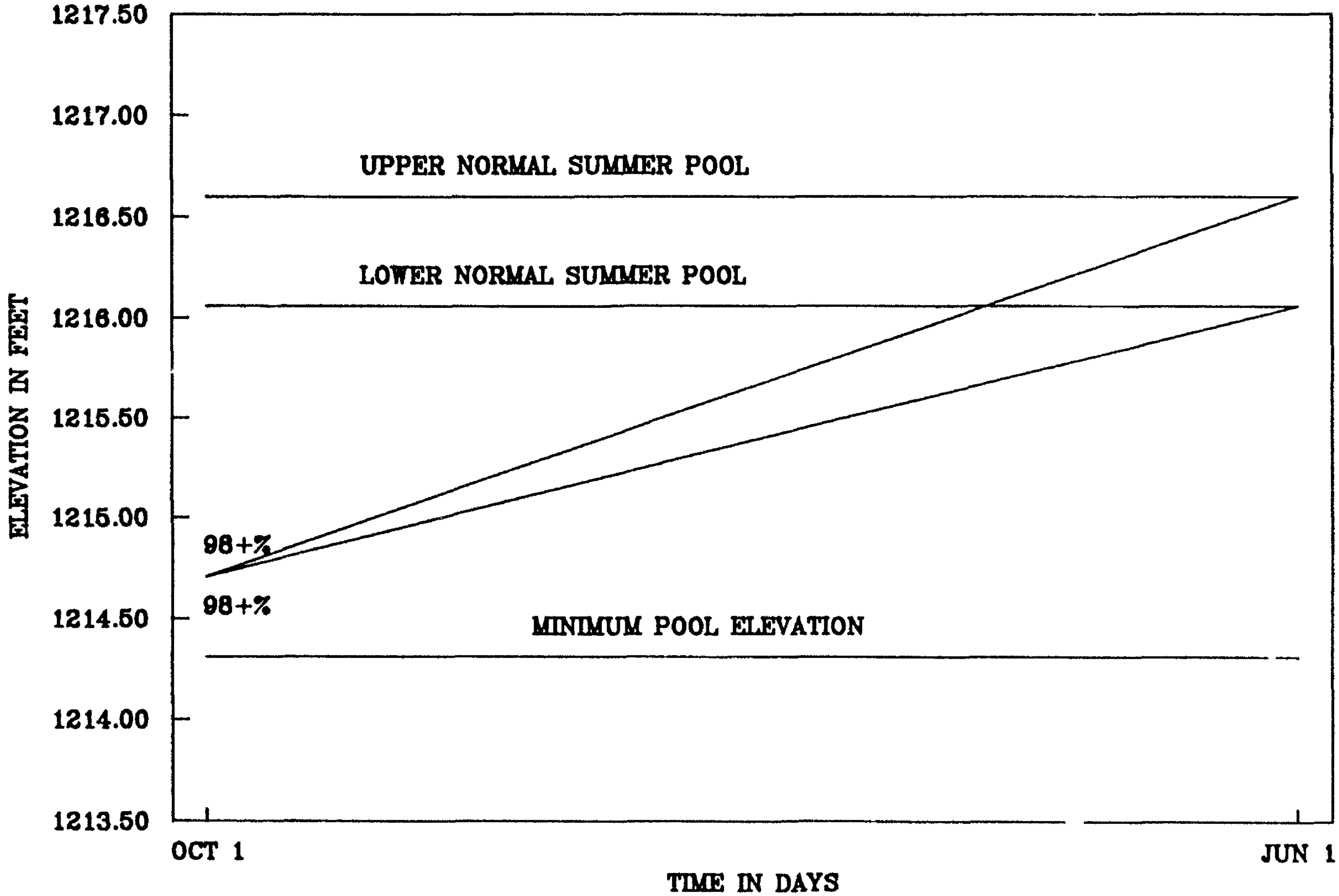
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

SANDY

OPTION 2: EVAPORATION + MINIMUM RELEASES



SANDY LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1214.71	1214.71
JUNE 1	1216.06	1216.60
OPTION 3: Evaporation & min. releases & additional flows (84 cfs)		
OCTOBER 1	1213.76	1213.76
JUNE 1	1216.06	1216.60

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

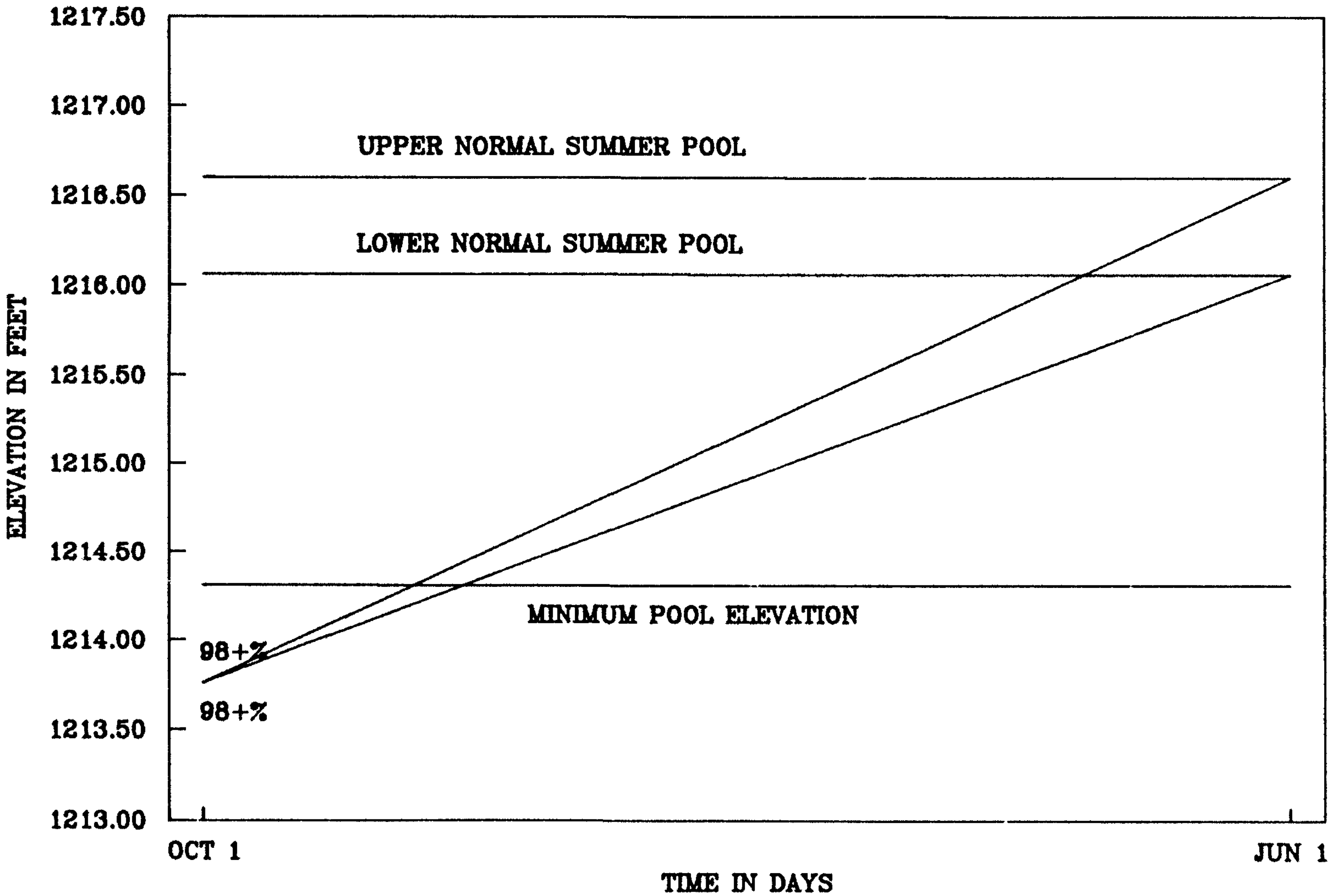
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

SANDY

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



SANDY LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1214.31
UPPER NORMAL SUMMER POOL = 1216.6
LOWER NORMAL SUMMER POOL = 1216.06

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1214.71	1214.71
JUNE 1	1216.06	1216.60
OPTION 3: Evaporation & min. releases & additional flows (84 cfs)		
OCTOBER 1	1213.76	1213.76
JUNE 1	1216.06	1216.60

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

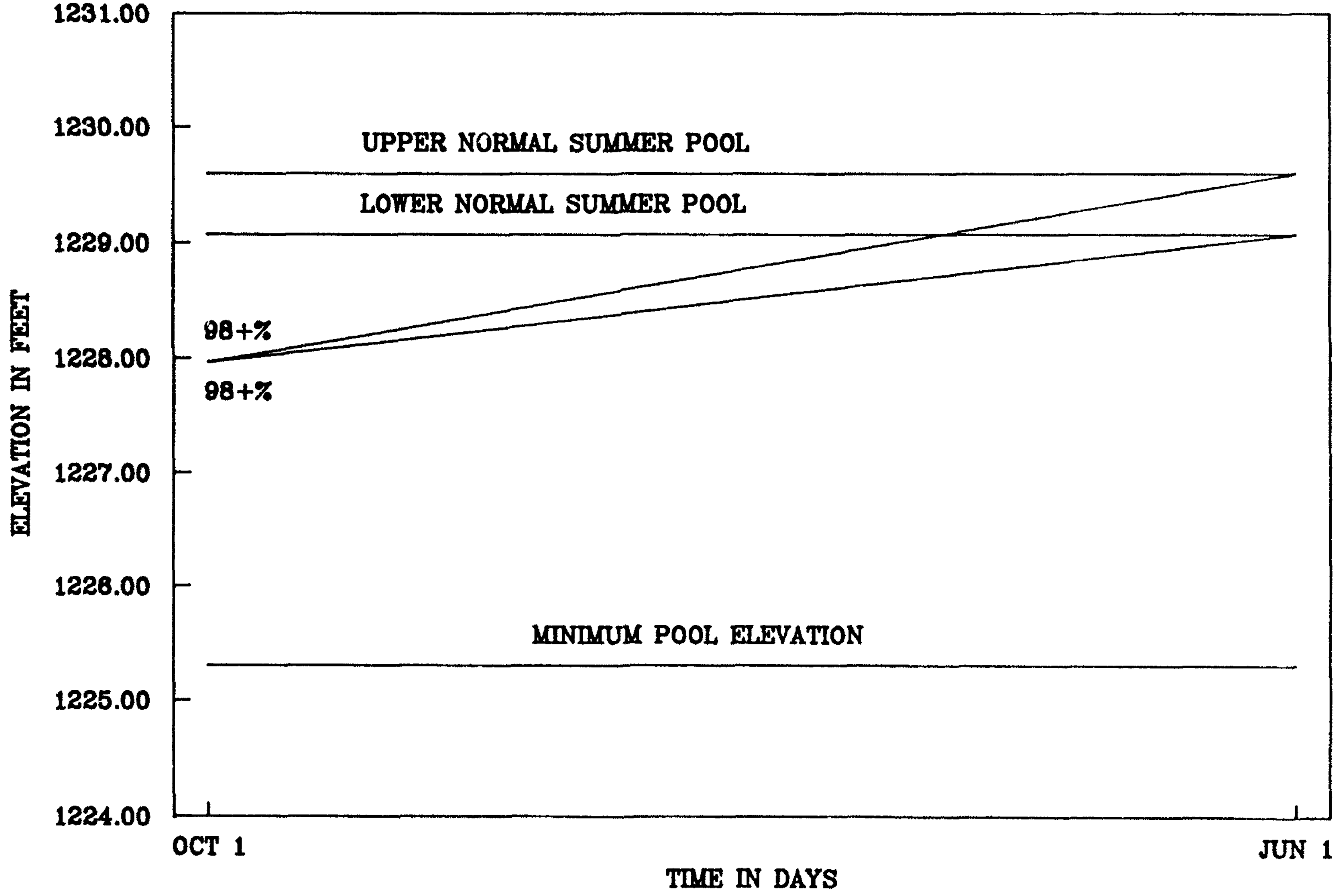
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

PINE

OPTION 2: EVAPORATION + MINIMUM RELEASES



PINE RIVER
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	98+% RECOVER-ABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVER-ABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (30 cfs)		
OCTOBER 1	1227.97	1227.97
JUNE 1	1229.07	1229.6
OPTION 3: Evaporation & min. releases & additional flows (126 cfs)		
OCTOBER 1	1226.20	1226.20
JUNE 1	1229.07	1229.6

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

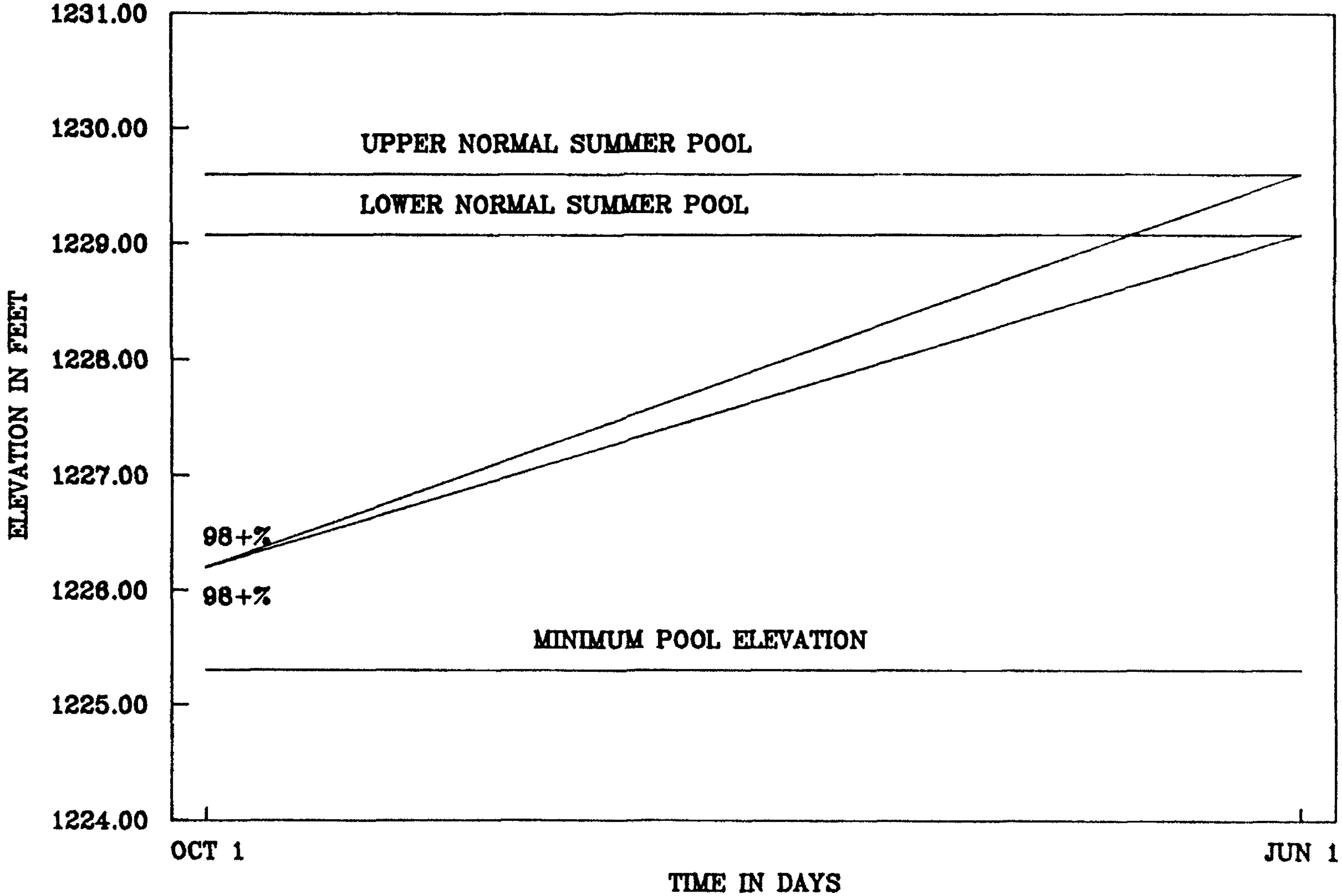
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERI 'G INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

PINE

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



PINE RIVER
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1225.32
UPPER NORMAL SUMMER POOL = 1229.6
LOWER NORMAL SUMMER POOL = 1229.07

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (30 cfs)		
OCTOBER 1	1227.97	1227.97
JUNE 1	1229.07	1229.6
OPTION 3: Evaporation & min. releases & additional flows (126 cfs)		
OCTOBER 1	1226.20	1226.20
JUNE 1	1229.07	1229.6

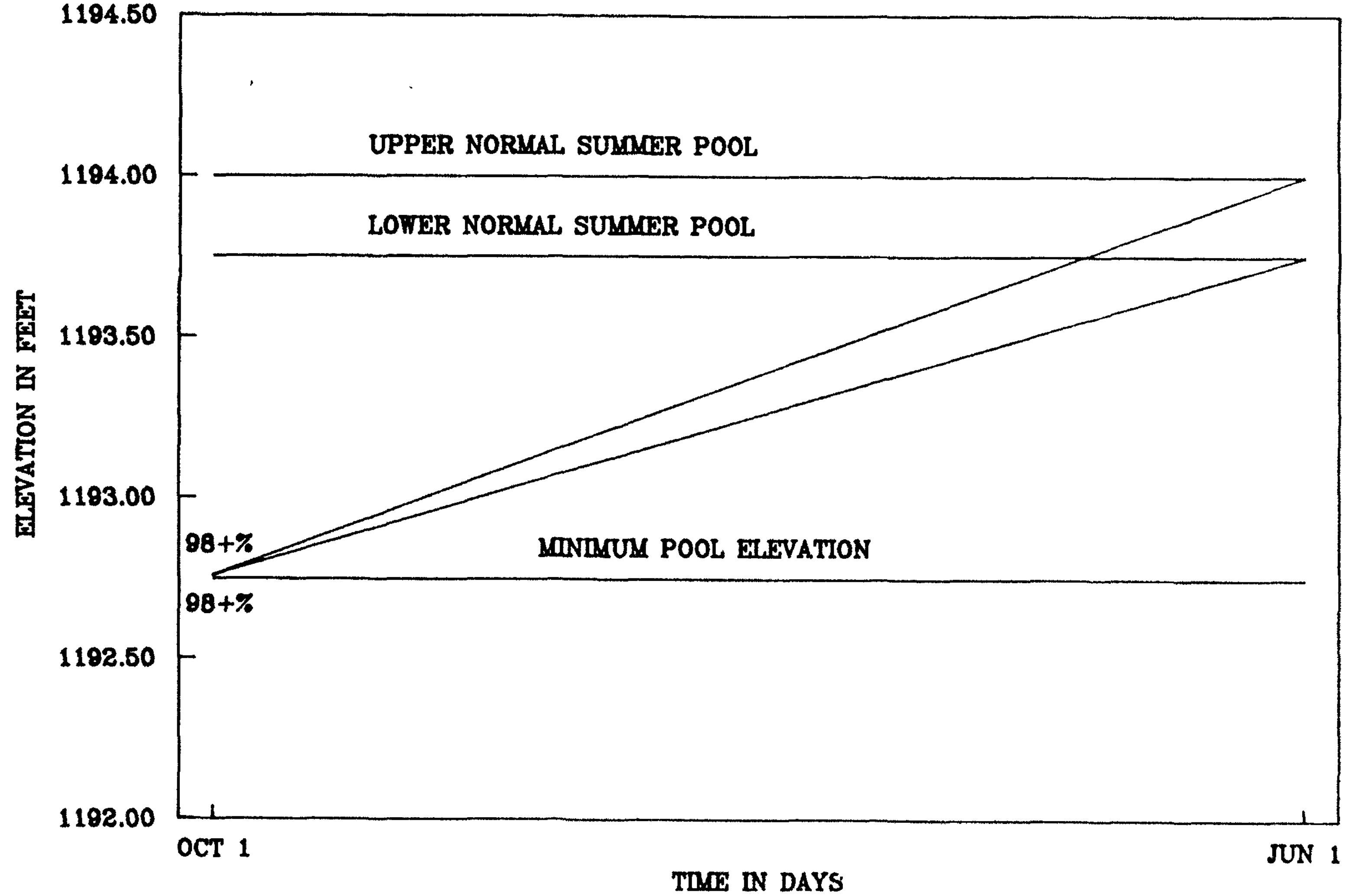
RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3
GULL

OPTION 2: EVAPORATION + MINIMUM RELEASES



GULL LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV = 1192.75
UPPER NORMAL SUMMER POOL = 1194.0
LOWER NORMAL SUMMER POOL = 1193.75

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1192.76	1192.76
JUNE 1	1193.75	1194.00
OPTION 3: Evaporation & min. releases & additional flows (120 cfs)		
OCTOBER 1	1192.15	1192.15
JUNE 1	1193.75	1194.00

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

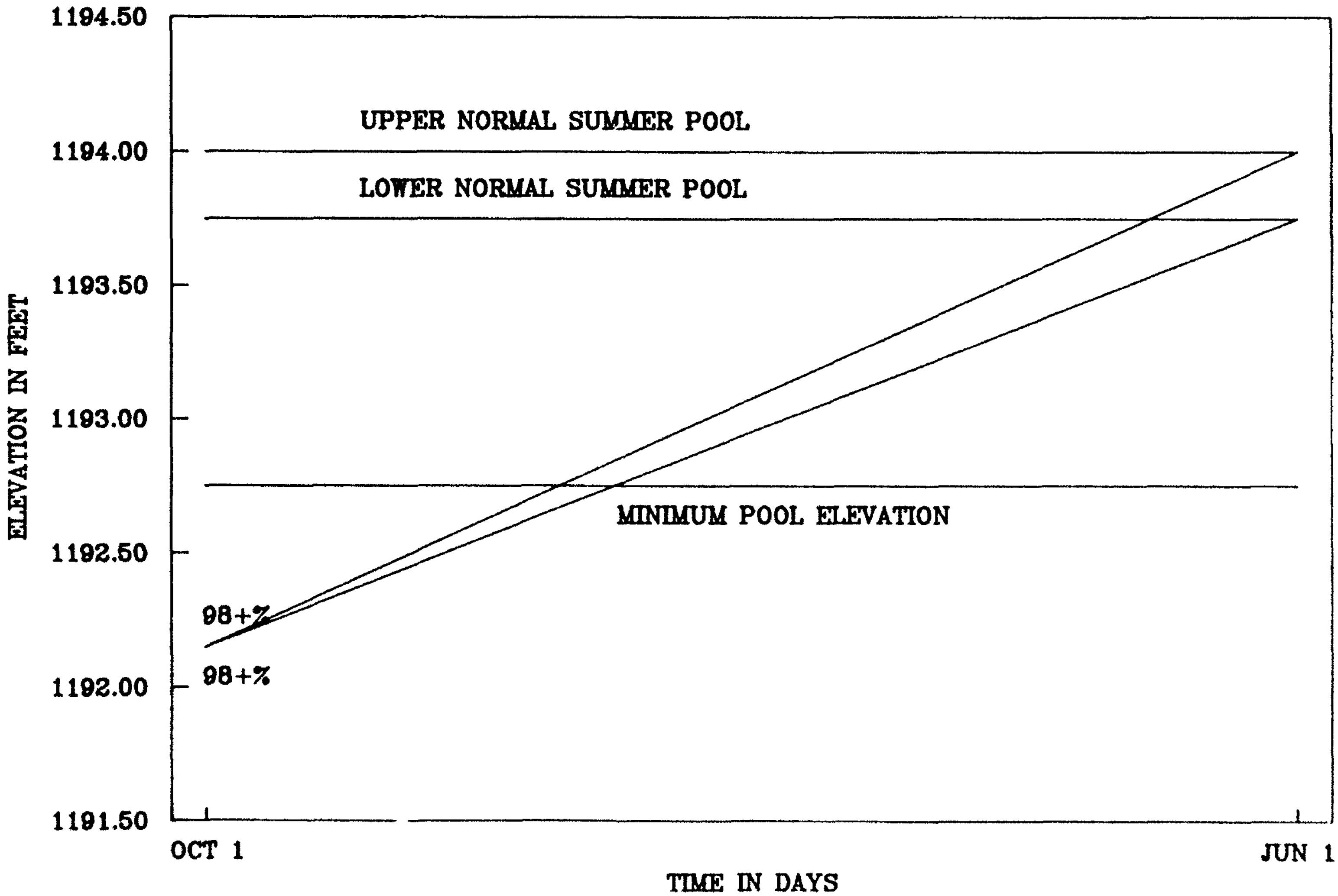
EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

RECOVERABILITY OF HEADWATERS RESERVOIR FOR: ILLUSTRATIVE EXAMPLE 3

GULL

OPTION 3: EVAP. + MIN. + ADDITIONAL RELEASES



GULL LAKE
RECOVERABILITY

PERIOD FROM: OCTOBER 1
TO: JUNE 1

ILLUSTRATIVE EXAMPLE 3: SANDY, PINE, & GULL ARE AT BOTTOM OF SUMMER BANDS. WINNI, LEECH, & POKE ARE 1 FOOT BELOW SUMMER BAND. SUPPLEMENTAL DISCHARGE (330 cfs) IS DETERMINED BY EQUAL DROP IN STAGE OF SANDY, PINE, & GULL. NO SUPPLEMENTAL RELEASES FOR WINNI, LEECH, & POKE.

MINIMUM POOL ELEV - 1192.75
UPPER NORMAL SUMMER POOL - 1194.0
LOWER NORMAL SUMMER POOL - 1193.75

DATE	98+% RECOVERABILITY TO LOWER SUMMER POOL ELEV.	98+% RECOVERABILITY TO UPPER SUMMER POOL ELEV.
OPTION 2: Evaporation plus minimum releases (20 cfs)		
OCTOBER 1	1192.76	1192.76
JUNE 1	1193.75	1194.00
OPTION 3: Evaporation & min. releases & additional flows (120 cfs)		
OCTOBER 1	1192.15	1192.15
JUNE 1	1193.75	1194.00

RECOVERABILITY PERCENTAGE AS LISTED ABOVE, REFLECTS THE PROBABILITY OF REFILLING TO GIVEN ELEVATION. THIS PROBABILITY WILL CHANGE AS THE STARTING ELEVATION VARIES.

EVAPORATION, AS USED IN THE PLOT AND TABLE ABOVE, IS THE NET LOSS IN POOL ELEVATION AFTER CONSIDERING INFLOWS AND MEASURED OUTFLOWS.

DATA REFLECTS OPTIONS UNDER STUDY. OPTIONS TO BE CHOOSEN WILL BE COORDINATED WITH OTHER AGENCIES AT A LATER DATE.

APPENDIX C

COMSUMPTIVE WATER USE ACCOUNTING

CONSUMPTIVE WATER USE ACCOUNTING

Introduction

1. Water is withdrawn from the Mississippi River and used for the following purposes:

Municipal water supply
Agricultural and horticultural irrigation
Industrial process water
Industrial cooling water
Hydropower generation
Navigation

Consumptive water use occurs when water is used for drinking, irrigation, incorporated into food or industrial products, lost to evaporation, or is otherwise diminished in quantity. Most water withdrawn from the Mississippi River for municipal supply and industrial cooling is not consumptively used, and is returned to the river after use.

There are a number of discharges to the Mississippi River from municipal waste treatment plans, industries, and from building air conditioning, where water withdrawn from wells augments river flow.

The combination of withdrawals, return flows, and river regulation at dams exerts a great influence on river discharge. The influence of these actions on river discharge is most marked during periods of extremely low river flow.

Objectives

2. The first objective of this analysis was to document the withdrawals and return flows to the Mississippi River that occur during periods of extremely low river discharge. The second objective was to document the effects of water use and river regulation on river flow.

Study Reach of River

3. The Mississippi River reach under consideration extends from the headwaters area at Lake Winnibigoshish Dam in Itasca County downstream through the Minneapolis and St. Paul metropolitan area to Lock and Dam 2 near Hastings, Minnesota. There are no significant water withdrawals for consumptive use from the Mississippi River upstream of Lake Winnibigoshish. Winni Dam is the upstream-most of the six headwaters dams operated by the Corps of Engineers.

Four miles below Lock and Dam 2 is the confluence with the St. Croix River. Demands for consumptive water use have historically not been constrained by river discharge downstream of the mouth of the St. Croix River, and releases from the headwaters dams contribute only a small fraction of river discharge below this point.

River Mile Registration

4. The St. Paul District, Corps of Engineers contracted with Minnesota State Planning Agency to assign river miles to the river reach from Lock and Dam 2 to Winnibigoshish Dam. The State Planning Agency used a computer geographic information system to conduct the river mile registration. Maps of the river with mile markers were generated by computer. The thalweg of the river was estimated as the line of river mile registration. The maps were prepared at a scale of 1:24,000, the same scale and projection as U.S. Geological Survey quadrangle maps. The river mile markers were transferred to corresponding USGS quads. The locations of water withdrawal and discharge points were identified to the nearest river mile.

The mile numbers and river mile locations correspond to the Minnesota State system of river mile registration, with the zero river mile mark at the point where the river flows out of the state. The river miles referred to in this report therefore do not correspond to the more commonly used system of river mile registration for the Upper Mississippi River 9-foot channel navigation system, which is measured in miles upstream of the mouth of the Ohio River.

State Water Use Permits

5. Appropriations for consumptive water use are regulated under a permit system by the MDNR. there are currently about 59 permits for water appropriation from the Mississippi River between Winnibigoshish Dam and Lock and Dam 2 (table 1).

Water withdrawal rates vary seasonally, as does consumptive use of water. The MDNR has authority to limit consumptive use of water during drought, following a priority system set by the State Legislature. Generally, limitations are first imposed on agricultural and horticultural irrigators, then industrial water users to reserve river discharge for the highest priority of use for municipal water supply and electrical generation. All water users are requested or ordered to limit withdrawal during drought conditions. Such actions were taken by the MDNR in the summer of 1988 to reduce appropriations from the Mississippi River.

Telephone Survey of Water Users

6. Permitted water users were surveyed by telephone to determine their actual rates of water withdrawal, rates of consumptive use, and rates of return flow to the river during the 1988 low flow period. Water users were asked to provide records or best estimates of actual water use during the latter part of July 1988. Operators of municipal waste treatment plants were also called to determine rates of return flow to the river during the latter part of July 1988. Data on return flows from building air conditioning in the Twin Cities metro area were obtained from the MDNR.

All parties contacted by telephone were most helpful and did provide the requested water use and discharge data. We wish to extend our thanks to those who assisted in the survey.

TABLE 1. MDNR Water Allocation Permittees on Mississippi River Between Winnibigoshish Dam and Lock and Dam 2.

1/11/89

Mississippi River

IRRIGATION

Major Crop Irrigation

Permit #	Permittee		
82-2061	Arnold Christensen 3026 Chippewa Dr. Grand Rapids, MN 55744 (218) 326-0761	Acres Permitted: 4 '87 Acres Reported: 2 Authorized GPM: 150 Authorized MGY: 1	Itasca County Section 13, T55N, R27W
83-2096	Allen Jackson 1410 Cardinal Drive Grand Rapids, MN 55744 (218) 326-4559	Acres Permitted: 28 '87 Acres Reported: 10 Authorized GPM: 265 Authorized MGY: 3.5	Itasca County Section 17, T54N, R24W
70-0390	Martin Wagner Route 1, Box 92 Royalton, MN 56373 (612) 584-5443	Acres Permitted: 135 '87 Acres Reported: 160 Authorized GPM: -- Authorized MGY: 19	Morrison County Section 4, T127N, R29W
74-3081	Verne B. Deering Route 5, Box 106 Little Falls, MN 56345 (612) 632-6951	Acres Permitted: 80 '87 Acres Reported: No App. Authorized GPM: 650 Authorized MGY: 3.3	Morrison County Section 23, T42N, R32W
79-3209	John A. Falk Route 6, Box 11 Little Falls, MN 56345 (612) 632-2242	Acres Permitted: 18 '87 Acres Reported: 18 Authorized GPM: 450 Authorized MGY: 3	Morrison County Section 19, T40N, R32W
85-3323	James LeDoux Route 5 Little Falls, MN 56345 (612) 749-2639	Acres Permitted: 60 '87 Acres Reported: 30 Authorized GPM: 500 Authorized MGY: 10	Morrison County Section 23, T42N, R32W
87-3318	Donald G. Popp Route 1, Box 94 Royalton, MN 56373 (612) 584-5811	Acres Permitted: 40 '87 Acres Reported: No App. Authorized GPM: 500 Authorized MGY: 11.6	Morrison County Section 8, T127N, R29W
50-0047	Whitney Land Co. Attn: A.W. Johnson P.O. Box 398 St. Cloud, MN 56302 (612) 252-1050	Acres Permitted: 35 '87 Acres Reported: No App. Authorized GPM: 600 Authorized MGY: 10	Sherburne County Section 12, T35N, R31W
50-0049	Houlton Farm c/o 1st Nat'l Bank 729 Main Street Elk River, MN 55330 (612) 441-2200	Acres Permitted: 135 '87 Acres Reported: 125 Authorized GPM: 800 Authorized MGY: 32	Sherburne County Section 4, T32N, R26W

Permit #	Permittee		
56-0204	Dechene Corp. Attn: Jame Dechene 18222 195th Street Big Lake, MN 55309 (612) 263-2714	Acres Permitted: 115 '87 Acres Reported: 10 Authorized GPM: 900 Authorized MGY: 8.2	Sherburne County Section 6 T32N, R27W
59-0324	A.R. Baldwin 4854 Thomas Ave. S. Minneapolis, MN 55410 (612) 926-3589	Acres Permitted: 40 '87 Acres Reported: No App. Authorized GPM: 500 Authorized MGY: 3.5	Sherburne County Section 24, T32N, R26W
60-0601	Derald Ewing & Sons Route 2, Co. Rd. 14 Big Lake, MN 55309 (612) 263-2849	Acres Permitted: 40 '87 Acres Reported: No Report Authorized GPM: 800 Authorized MGY: 13.3	Sherburne County Section 32, T33N, R27W
61-0107	Lawrence Nadeau 16713 County Rd. 14 Elk River, MN 55330 (612) 263-2837	Acres Permitted: 20 '87 Acres Reported: 5 Authorized GPM: 600 Authorized MGY: 6.0	Sherburne County Section 34, T33N, R27W
61-0360	Verle Ewing & Sons Attn: James A. Ewing 18565 Co. Rd. 14 Big Lake, MN 55309 (612) 263-2270	Acres Permitted: 35 '87 Acres Reported: 24 Authorized GPM: 500 Authorized MGY: 10	Sherburne County Section 31, 32 T33N, R27W
64-0078	Peterson Brothers 19993 182nd Ave. Big Lake, MN 55309 (612) 263-2322	Acres Permitted: 80 '87 Acres Reported: 110 Authorized GPM: -- Authorized MGY: 13.3	Sherburne County Section 12, T33N, R29W
76-3402	Edward E. Goenner Route 2, Box 132 Clear Lake, MN 55319 (612) 743-2346	Acres Permitted: 80 '87 Acres Reported: 75 Authorized GPM; 650 Authorized MGY: 16.7	Sherburne County Section 4, 5 T33N, R29W Section 32, T34N, R29W
82-3117	Riverside Farms c/o Joseph H. Nathe 15238 Adams Street Elk River, MN 55330 (612) 427-6023	Acres Permitted: 23 '87 Acres Reported: 24 Authorized GPM: 400 Authorized MGY: 4	Sherburne County Section 24, T32N, R26W
84-3319	NSP-Sherco G.V. Welk 414 Nicollet Mall Minneapolis, MN 55104 (612) 330-5633	Acres Permitted: 10 '87 Acres Reported: 5 Authorized GPM: 250 Authorized MGY: 10	Sherburne County Section 12, T33N, R29W

Permit #	Permittee		
51-0033	Lyle Wolhart Attn: Myron Wolhart 039122 Cty. Rd. 1 St. Cloud, MN 56301 (218) 251-0153	Acres Permitted: 100 '87 Acres Reported: No Report Authorized GPM: 600 Authorized MGY: 14	Stearns County Section 28, T126N, R28W
76-3286	Whitney Land Co. Attn: A.W. Johnson 505½ St. Germain St. Cloud, MN 56302 (612) 252-1050	Acres Permitted: 188 '87 Acres Reported: 158 Authorized GPM: 650 Authorized MGY: 31.4	Stearns County Section 21, T123N, R27W
71-0394	Vernon C. Kolles 538 Roosevelt Circle Elk River, MN 55330 (612) 441-3119	Acres Permitted: 85 '87 Acres Reported: No App. Authorized GPM: 500 Authorized MGY: 45	Wright County Section 18, T121N, R23W Section 13, T121N, R24W
71-0476	Richard Lefbvre 9244 Parish Ave. N.E. Elk River, MN 55330 (612) 441-1807	Acres Permitted: 96 '87 Acres Reported: 70 Authorized GPM: 398 Authorized MGY: 6	Wright County Section 14, T121N, R23W
72-0181	Carl A. Swenson Route 2, Box 154 Monticello, MN 55362 (612) 295-5950	Acres Permitted: 75 '87 Acres Reported: No App. Authorized GPM: 450 Authorized MGY: 54	Wright County Section 10, T121N, R24W
77-3508	Donald Lemke 2 Roger Road St. Cloud, MN 56301 (612) 252-1621	Acres Permitted: 40 '87 Acres Reported: No Report Authorized GPM: 500 Authorized MGY: 16.6	Wright County Section 1, T122N, R27W
56-0132	Riverside Farms c/o Joseph H. Nathe 15238 Adams Street Elk River, MN 55330 (612) 427-6023	Acres Permitted: 76 '87 Acres Reported: 76 Authorized GPM: 800 Authorized MGY: 14.6	Anoka County Section 24, T32N, R25W
75-6095	Joseph E. Hipp Box 12572 New Brighton, MN 55112 (612) 427-2069	Acres Permitted: 120 '87 Acres Reported: No App. Authorized GPM: 300 Authorized MGY: 14	Anoka County Section 32, T32N, R25W
77-6367	Dorothy H. Hanson c/o James M. Martin 3740 Union Terrace Minneapolis, MN 55441 (612) 546-1338	Acres Permitted: 40 '87 Acres Reported: No App. Authorized GPM: 500 Authorized MGY: 6.3	Anoka County Section 33, T32N, R25W
55-0246	Thomas Banks c/o Robert Banks P.O. Box 10797 Reno, NV 89510 (702) 786-9800	Acres Permitted: 160 '87 Acres Reported: No App. Authorized GPM: 1000 Authorized MGY: 26	Hennepin County Section 11, T120N, R22W

Wild Rice Irrigation

Permit #	Permittee		
71-0396	Willys O. Nord Route 4, Box 102 Bemidji, MN 56601 (218) 751-8244	Acres Permitted: 67 '87 Acres Reported: No App. Authorized GPM: Unspecified Authorized MGY: 5	Beltrami County Section 4, T146N, R32W
69-0431	Vomela Wild Rice Co. Attn: George Shetka Fleming Rt. 64D2 Aitkin, MN 56431 (218) 927-6617	Acres Permitted: 600 '87 Acres Reported: 536 Authorized GPM: 16,000 Authorized MGY: 400	Aitkin County Section 6, T48N, R25W
70-0430	Orjala Carl Attn: Christopher Ratuski Fleming Tr, Box 31 Aitkin, MN 56431 (218) 927-2002	Acres Permitted: 120 '87 Acres Reported: No App. Authorized GPM: 2000 Authorized MGY: 60	Aitkin County Section 22, T48N, R26W
71-1008	Manomin Development Co. Attn: Al Hedstrom 18 Spring Farm Lane St. Paul, MN 55127 (612) 484-4406	Acres Permitted: 1000 '87 Acres Reported: 500 Authorized GPM: 8000 Authorized MGY: 888	Aitkin County Section 1 T47N, R27W
76-2022	Percy Wayne Harrel 12637 Mason Forest St. Louis, MO 63141 (314) 434-7878	Acres Permitted: 300 '87 Acres Reported: 250 Authorized GPM: 2300 Authorized MGY: 100	Aitkin County Section 27, 28, 34 T50N, R24W
77-2194	Kosbau Brothers Inc. Box 599 Grand Rapids, MN 55744 (218) 326-5456	Acres Permitted: 800 '87 Acres Reported: No App. Authorized GPM: 6000 Authorized MGY: 261	Aitkin County Section 15, 16, 17 T48N, R26W
68-1496	Francis Brink Eino Sinkola Ball Club Route Deer River, MN 56636 (218) 246-8976	Acres Permitted: 40 '87 Acres Reported: 40 Authorized GPM: Unspecified Authorized MGY: 6.7	Itasca County Section 4, T144N, R25W
59-0507	Marvel T. Severson Star Route Box 306 Deerwood, MN 56444 (218) 546-6136	Acres Permitted: 40 '87 Acres Reported: No App. Authorized GPM: Unspecified Authorized MGY: 13.1	Crow Wing County Section 9, T135N, R27W

NON-CROP IRRIGATION

Golf Course Irrigation

63-0418	City of Little Falls 100 N.E. 7th Ave. Little Falls, MN 56345 (612) 632-3584	Acres Permitted: 47 '87 Acres Reported: 47 Authorized GPM: 360 Authorized MGY: 23	Morrison County Section 18, T40N, R32W

Permit #	Permittee		
79-3254	St. Cloud Country Club P.O. Box 1064 St. Cloud, MN 56302 (612) 253-5250	Acres Permitted: 30 '87 Acres Reported: 30 Authorized GPM: 460 Authorized MGY: 8.3	Stearns County Section 25, T124N, R28W

Landscaping
Non-Irrigation

77-3705	Ind. School Dist. 748 Attn: W. Galarneanlt P.O. Box 328 Sartel, MN 56377 (612) 253-2200	Acres Permitted: 38 '87 Acres Reported: 38 Authorized GPM: 450 Authorized MGY: 11	Stearns County Section 21, T125N, R28W
88-3156	St. Cloud State Univ. Attn: Jan Peterson, City Attorney Administrative Services Room 121 St. Cloud, MN 56301 (612) 255-2286	Acres Permitted: 7 '87 Acres Reported: No Report Authorized GPM: 15.5 Authorized MGY: 1.6	Stearns County Section 13, T124N, R28W

Industrial Use

75-2147	Blandin Paper Attn: Peter Harris 115 1st St. S.W. Grand Rapids, MN 55744 (218) 327-6306	Authorized GPM: 51,600 Authorized MGY: 16,000 '87 GPM Reported: -- '87 MGY Reported: 7,911	Itasca County Section 20, T55N, R25W
79-2012	Blandin Wood Products Attn: Curt R. Firman 502 County Rd. 63 Grand Rapids, MN 55744 (218) 327-6376	Authorized GPM: 325 Authorized MGY: 180 '87 GPM Reported: -- '87 MGY Reported: 30,069	Itasca County Section 19, T55N, R25W
75-3228	Potlatch Corp. Attn: Harry Dean 1801 Mill Ave. N.E. Brainerd, MN 56401 (218) 828-3200	Authorized GPM: 6300 Authorized MGY: 1205 '87 GPM Reported: 2102 '87 MGY Reported: 1,105	Crow Wing County Section 18, T45N, R30W
87-3113	Hennepin Paper Co. Attn: Morris Bellefeuille 100 S.W. 5th Ave. Little Falls, MN 56345 (612) 632-3684	Authorized GPM: 2000 Authorized MGY: 800 '87 GPM Reported: No Report '87 MGY Reported: --	Morrison County Section 19, T129N, R29W
80-3043	Champion International Attn: D.F. Bonistall P.O. Box 338 Sartell, MN 56377 (612) 251-6511	Authorized GPM: 8333 Authorized MGY: 3865 '87 GPM Reported: 8751 '87 MGY Reported: 3,830	Benton County Section 9, T36N, R31W

Permit #	Permittee		
77-3898	Barton Sand & Gravel Attn: Sue Turner 10633 89th Ave. N. Maple Grove, MN (612) 425-4191	Authorized GPM: 600 Authorized MGY: 29 '87 GPM Reported: 600 '87 MGY Reported: 12	Wright County Section 24, T122N, R26W
75-6240	Ford Motor Co. Attn: R.W. Johnson 966 S. Mississippi River Blvd. St. Paul, MN 55116 (612) 696-0623	Authorized GPM: 600 Authorized MGY: 305 '87 GPM Reported: 200 '87 MGY Reported: 62	Ramsey County Section 17, T28N, R23W

Municipal Waterworks

80-3102	City of St. Cloud Water Utility City Hall St. Cloud, MN 56301 (612) 255-7225	Authorized GPM: 6944 Authorized MGY: 2500 '87 GPM Reported: 3745 '87 MGY Reported: 1,968	Stearns County Section 11, T124N, R28W
63-016[illegible]	City of Brooklyn Center Attn: Dick Ploumen 6301 Shingle Creek Brooklyn Center, MN 55430 (612) 561-5440	Authorized GPM: 1000 Authorized MGY: 500 '87 GPM Reported: No App. '87 MGY Reported: No App.	Hennepin County Section 36, T119N, R21W
78-6216	City of Minneapolis 43rd and Marshall N.E. Minneapolis, MN 55421 (612) 788-5881	Authorized GPM: 240,000 Authorized MGY: 125,000 '87 GPM Reported: -- '87 MGY Reported: 26,963	Anoka County Section 34, T30N, R24W
75-6230	City of St. Paul Board of Water Comm. 500 City Hall Annex St. Paul, MN 55102 (612) 298-4100	Authorized GPM: 76,418 Authorized MGY: 20,000 '87 GPM Reported: -- '87 MGY Reported: 18,090	Anoka County Section 10, T30N, R24W

Power Generation

66-1172	NSP-Monticello 414 Nicollet Mall Minneapolis, MN 55401 (612) 337-2183	Authorized GPM: 289,500 Authorized MGY: 152,117 '87 GPM Reported: 240,000 '87 MGY Reported: 153,614	Wright County Section 33, T122N, R25W
71-0938	NSP Sherco ERAD 2nd Floor 414 Nicollet Mall Minneapolis, MN 55401 (612) 261-4100	Authorized GPM: 30,000 Authorized MGY: 9310 '87 GPM Reported: 6558 '87 MGY Reported: 3446	Sherburne County Section 12, T33N, R29W

59-0225	United Power Assn. Elk River Attn: Dan McConnon Elk River, MN 55330 (612) 441-3121	Authorized GPM: 50,000 Authorized MGY: 12,000 '87 GPM Reported: 25,000 '87 MGY Reported: 35	Sherburne County Section 3, T32N, R26W
62-0457	NSP-Riverside 414 Nicollet Mall Minneapolis, MN 55401 (612) 337-2183	Authorized GPM: Unspecified Authorized MGY: 179,000 '87 GPM Reported: 110,000 '87 MGY Reported: 31,626	Hennepin County Section 39, T113N, R14W
76-6345	NSP-Riverside 414 Nicollet Mall Minneapolis, MN 55401 (612) 337-2183	Authorized GPM: 270,300 Authorized MGY: 69,732 '87 GPM Reported: 75,000 '87 MGY Reported: 9,014	Hennepin County Section 3, T29N, R24W
76-6347	NSP High Bridge 414 Nicollet Mall Minneapolis, MN 55401 (612) 221-4535	Authorized GPM: 220,000 Authorized MGY: 114,050 '87 GPM Reported: 221,800 '87 MGY Reported: 59,000	Ramsey County Section 12, T28N, R23W
86-6219	Univ. of Minnesota-SAFHL Roger Arndt Miss. River at 3rd Minneapolis, MN 55414 (612) 625-1540	Authorized GPM: 22,500 Authorized MGY: 120 '87 GPM Reported: 200 '87 MGY Reported: 12,000 Hydro power	Hennepin County Section 23, T29N, R24W

Water Level Maintenance

65-0069	City of Minneapolis Park & Recreation Brd. 310 S. 4th Ave. Minneapolis, MN 55415 (612) 348-2220	Authorized GPM: 12,000 Authorized MGY: 10 '87 GPM Reported: 12,000 '87 MGY Reported: 273	Hennepin County Section 10, T29N, R24W

1200 cfs Q limit, after 15 June

Fish Hatcheries

62-0023	Cuyuna Range Consv. P.O. Box 136 Ironton, MN 56455 (218) 546-6414	Authorized GPM: -- Authorized MGY: 47.1 '87 GPM Reported: 600 '87 MGY Reported: 16	Crow Wing County Section 25, T136N, R26W
69-0114	US EPA-Monticello Monticello Fld. Station P.O. Box 500 Monticello, MN 55362 (612) 295-5145	Authorized GPM: 2600 Authorized MGY: 1200 '87 GPM Reported: 1745 '87 MGY Reported: 749	Wright County Section 33, T122N, R25W

Flow rates were reported in various units of measurement, and were converted to cubic feet per second to enable direct comparisons to river discharge. Flow rates were rounded to the nearest 0.1 cfs. Locations of water withdrawals and return flows were estimated to the nearest river mile. Building air conditioning return flows, which return to the Mississippi River in significant quantities only at St. Paul and Minneapolis, pass through the storm drain systems to the river. These return flows were assumed to enter the river at river miles corresponding to the city centers.

Table 2 provides a listing of the reported rates of water appropriations, consumptive use, and return flows to the river for the MDNR permitted water union. **** (use lotus file WATERBUD.WK1)****.

The following are results of the telephone survey:

Minnesota Power Clay Boswell Generating Plan

RM 506

Contact: Dale Kreager 218-722-2641

The Clay Boswell plant is a 4-unit steam electric generating plant rated at 1005 Megawatts. Units one and two use river water for once-through cooling. Units 3 and 4 have a closed loop cooling system with cooling towers to dissipate waste heat. Only evaporation make-up is consumed. Small amounts of water are appropriated for other in-plant uses, ash ponds, etc. The rate of appropriation during the latter half of July 1988 was maximal, with full operation of all four units. Total appropriation was 261.9 cfs, 17.2 cfs was consumed, and return flow to the river was 244.7 cfs. These values are daily averages based on July total appropriation figures reported to the MDNR. Plant operation and water use was essentially constant during the month of July.

Blandin Paper

RM 504

Contact: Peter Harris 218-327-6306

An average of 60.7 cfs was withdrawn from the river during the latter part of July 1988 for cooling and industrial process water. Non-contact cooling water return flow to the river was 42.6 cfs. Industrial process water and sanitary waste, a total of 18.1 cfs, was piped to the municipal treatment plants. Consumptive use of river water was 0.5 cfs. These values are representative of water use during full production in a low river discharge period. Plant expansion is being considered, but the present rates of water use should not have to increase.

Blandin Wood Products

RM 504

Contact: Curt Firman 218-327-6376

The Blandin Wood Products plant withdraws 0.7 cfs from the river, and nearly all is consumed in process. Non-contact cooling water is withdrawn from wells. Return flow to the river is 0.1 cfs.

City of Grand Rapids Waste Treatment Plant

RM 502

Contact: Jim Ackerman 218-326-9489

The City of Grand Rapids treats both industrial and domestic wastewater. All water for domestic use and some water for industrial use is withdrawn from wells. The average rate of return flow to the river from the treatment plants in the latter half of July 1988 was 17.8 cfs.

City of Aitkin Waste Treatment Plant

RM 382

Contact: Willie Fossum 218-927-3222

The City of Aitkin obtains water for domestic use from wells. The July 1988 average rate of discharge from the wastewater treatment plant was 0.5 cfs.

Potlach - Brainerd Paper Mill

RM 329

Contact: Harry Dean 218-828-3200

The Potlach mill has maximum water use requirements in the summer. The withdrawal rate was 4.7 cfs. The maximum rate of consumptive use was 0.2 cfs. Return flow to the river was 4.5 cfs. Usually, consumptive use is negligible, and withdrawal nearly equals discharge.

City of Brainerd Waste Water Treatment Plant

RM 329

Contact: Pete Ledoux 218-829-5700

The Brainerd municipal water supply is drawn from wells. The average daily discharge from the treatment plant in the latter part of July 1988 was 3.7 cfs.

Hennepin Paper Co. - Little Falls

RM 290

Contact: Morris Bellefuille

The normal rate of withdrawal at the Hennepin Paper Co. mill is 2.7 cfs. About 85%, or 2.3 cfs, is returned to the river, and 0.4 cfs are consumed in process and by evaporation. The rate of withdrawal at the Hennepin mill is reduced during periods of low river discharge.

City of Little Falls Waste Water Treatment Plant

RM 290

Contact: Greg McGillis 612-632-8200

The City of Little Falls obtains its municipal water supply from wells. The treatment plant discharged and 1 cfs during the latter part of July 1989.

Champion International - Sartell Paper Mill

RM 258

Contact: Dave Bonistall 612-251-6511

The average rate of withdrawal at the Champion plant was 18.0 cfs during July 1988, average consumptive use was 0.9 cfs, and average rate of return flow to the river was 17.1 cfs. The company has requested an increase in the maximum permitted rate of appropriation to accommodate plant expansion. Plant operators encountered water quality problems in August 1988 as river discharge increased due to high algae concentrations that were flushed downstream following the extended low flow period.

City of St. Cloud Municipal Water Supply

RM 253

Contact: Tom Dunn 612-255-7226

The City of St. Cloud relies primarily on the Mississippi River for its municipal water supply. The City does have a well field with a maximum pumping rate of about 2.3 cfs. The well field is used to supplement withdrawals from the river when necessary and to manage quality problems with the river water. The city has a maximum plant capacity for pumping 14 cfs from the river, and did withdraw at that rate in July 1988. A sprinkling ban was instituted in the summer of 1988 to maintain demand to within system capacity. Plans are being developed to increase capacity of the municipal water supply system, but sources for the increased capacity have not yet been selected.

City of St. Cloud Wastewater Treatment Plant

RM 253

Contact: Ken Robinson 612-255-7226

The average July 1988 discharge from the St. Cloud wastewater treatment plant was 10.9 cfs.

Northern States Power Company - Sherco Generating Plant

RM 229

Contact: Dave Heberling 612-330-1925

The Sherco generating plant is a three unit coal burning plant with a total rated capacity of 2300 megawatts. The plant has a closed-cycle cooling system where water is reused for cooling after being run through cooling towers. The Sherco is operated in a closed-cycle cooling mode year round. Water is withdrawn from the river to make up for evaporative losses in the cooling system. The maximum rate of withdrawal is 67 cfs with all three units operating. The average withdrawal rate during July 1988 was 55 cfs, and consumptive was averaged 38 cfs. The Sherco plant intake is on an unimpounded reach of the river, and is dependent on sufficient river discharge to provide adequate water surface elevation for the pump intake. The critical flow for the Sherco intake is between 200 and 250 cfs. River discharge at the Sherco plant remained above 350 cfs during July 1988 (the lowest recorded release from the dam at St. Cloud was 353 cfs on July 27.)

Barton Sand and Gravel

RM 229

Contact: Sue Turner 612-425-4191

Barton Sand and Gravel is a gravel mining operation which uses river water to wash gravel. Water is drawn from the river from April through August

at an average rate of 1.3 cfs. The water is ponded next to the river for solids removal, and it can be assumed that it all returns to the river.

Northern States Power Company - Monticello Nuclear Generating Plant

RM 225
Contact: Dave Heberling 612-330-1925

The Monticello Nuclear Generating Plant is a single unit boiling water nuclear reactor with a rated generating capacity of 545 megawatts. The Monticello plant cooling system uses river water in a helper-cycle where water is pumped through cooling towers prior to being discharged.

The State permits for water appropriation at the Monticello Plant have conditions that constrain operation. NSP is allowed to withdraw up to 645 cfs, but not more than 75% of river discharge. Therefore, when river discharge falls below 860 cfs, a portion of the cooling tower discharge must be recirculated to the condensers.

Plant operation is also constrained by State discharge permit conditions for protection of water quality and aquatic life in the river. The permit conditions limit the mixed river temperature downstream and impose a maximum temperature increases above ambient.

The combination of permit requirements, low river discharge, and high river with temperature can seasonally restrict the amount of condenser cooling and consequently electrical generation. Northern States Power Company makes heat and electrical power production at the Monticello Plant to stay within permit operational constraints and to avoid significant adverse thermal effects on aquatic life in the river. During times during July 1988, the combined physical and regulatory water use constraints caused NSP to limit the Monticello Plant to 70% of its generating capacity.

The electrical generating shortfall from the Monticello plant of up to 160 megawatts in 1988 occurred at a time of peak electrical demand, primarily from air conditioning. NSP power purchases were approximately 25%, or

1726 megawatts, of the total peak demand of 6903 megawatts. The added weekly costs to NSP residential customers from a 25% generating reduction at the Monticello Plant is estimated to be $0.07 to $0.09.

The Monticello Plant, like the Sherco Plant, is on an unimpounded reach of the river, and requires between 200 and 250 cfs of flow to maintain sufficient depth of water at the intake.

The actual rate of water appropriation at the Monticello Plant in the latter part of July 1988 varied, at 75% of river discharge. Consumptive water use, primarily to evaporative losses from the cooling towers, averaged 10 cfs.

United Power Association - Elk River Generating Plant

RM 209

Contact: Dan McConnon 612-441-3121

The Elk River Power Plant is a three-unit generating plant rated at 50 megawatts that has recently been modified to burn processed municipal solid waste, or refuse-derived fuel. The plant uses river water to cool the steam condensers in a once-through cooling system. Maximum pumping rate for cooling is 111.5 cfs. Virtually no water is consumptively used in the once-through cooling system. Wells provide water for other in-plant uses.

City of Elk River - Wastewater Treatment Plant

RM 209

Contact: Darryl Mac 612-441-5136

The City of Elk River obtains its municipal water supply from wells. Discharge from the wastewater treatment plant averaged 0.7 cfs during July 1988.

Metropolitan Waste Control Commission - Anoka Plant

RM 191

Contact: Ray Odde 612-222-8423

The July 1988 average discharge from the Anoka MWCC waste treatment plant was 3.5 cfs.

City of St. Paul - Municipal Water Supply

RM 188

Contact: Tom Johnson 612-298-4100

St. Paul obtains water from a well field, a series of lakes and reservoirs, and from the river. With water use restrictions in effect, St. Paul can go for about 45 days without taking water from the river before levels in the water supply lakes and reservoirs become unacceptably low. During July 1989, with restrictions on outside water uses in effect, the City withdrew an average of 34.8 cfs. Wastewater from the City of St. Paul is treated by the Metropolitan Waste Control Commission, at the Metro plant.

City of Minneapolis - Municipal Water Supply

RM 184

Contact: Adam Kramer 612-788-5881

The City of Minneapolis obtains all its municipal water supply from the river. During the latter part of July 1988, with restrictions on outside water uses in effect, the city pumped an average of 167.4 cfs from the river. Wastewater from the City of Minneapolis is treated by the Metropolitan Waste Control Commission at a number of treatment plants.

Northern States Power Company - Riverside Generating Plant

RM 183

Contact: Dave Heberling 612-330-1925

The Riverside plant is a coal-fired electrical generating plant rated at 366 megawatts. The plant used a maximum of 376 cfs for its once-through cooling system during July 1988. Approximately 1 cfs was consumed.

Combined Return Flows from Minneapolis Building Air Conditioning

RM 178 (Assumed)

Contact: James Japs (Minnesota DNR Division of Waters) 612-297-2835

A number of buildings in Hennepin County, mostly in the City of Minneapolis, withdraw water from wells for geothermal air conditioning. Following use for air conditioning, the water from each building is viciously discharged to city lakes, the Metro sanitary drains, or most commonly to the city storm drains where the water is eventually discharged to the river. The best current estimate of combined return flows from Hennepin county, based on reported use data for July 1987, is 43.9 cfs. This estimate does not include flows from buildings that apparently discharge to city lakes or other watercourses. The estimate is conservatively high, because the geothermal water users tend to report maximal permitted rates of flow.

The assumed river mile discharge point approximates the Minneapolis city center, where most of the storm drains that convey return flows from building air conditioning discharge to the river.

The Minnesota DNR, which administers a permit system for groundwater withdrawals for geothermal heating and cooling, is in the process of conducting a detailed survey to determine actual rates of water use and discharge locations.

Ford Motor Company

RM 172

Contact: Ralph Cook 612-696-0628

The Ford plant uses an average of 0.5 cfs of river water for industrial processes, 0.1 cfs is consumptively used by evaporative losses, and an average of 0.7 cfs of river water was used for horticultural irrigation at the plant during July 1988. There is no discharge to the river from the plant. Wastes are discharged to the Metro sewer system.

The Northern States Power Company - High Bridge Power Plant

RM 165

Contact: Dave Heberling 612-330-1925

The High Bridge power plant is a coal-fired plant rated at 306 megawatts. The plant used an average of 401 cfs and consumed approximately 1 cfs in the once-through cooling system during July 1988.

Combined Flows - St. Paul Building Air Conditioning

RM 164 (Assumed)

Contact: James Japs (Minnesota DNR Division of Waters) 612-297-2835

The best current estimate for return flows from St. Paul building air conditioning is 32.5 cfs. The estimate is conservatively high, and based on reported use for July 1987. The point of return flows via the city storm drains is assumed to be near the city center.

Metropolitan Waste Control Commission - Metro Waste Treatment Plant

RM 160

Contact: Ray Odde 612-22-8423

The Metro Plant is the largest of the Metropolitan Waste Control Commission treatment plants, and it serves much of the Minneapolis and St. Paul area.

Discharge from the plant varies considerably. The July 1988 average discharge rate during the period when restrictions on outside water use were in effect was 352 cfs.

Metropolitan Waste Control Commission - Rosemount Waste Treatment Plant

RM 147

Contact: Ray Odde 612-222-8423

The Rosemount wastewater treatment plant discharged an average of 0.7 cfs during July 1988.

Metropolitan Waste Control Commission - Cottage Grove Waste Treatment Plant

RM 143

Contact: Ray Odde 612-222-8423

The Cottage Grove wastewater treatment plant discharged an average of 2.2 cfs during July 1988.

Minnesota River

Metropolitan Waste Control Commission - Blue Lake Waste Treatment Plant

Contact: Ray Odde 612-222-8423

The Blue Lake wastewater treatment plant discharged an average of 32.5 cfs during July 1988.

Metropolitan Waste Control Commission - Seneca Waste Treatment Plant

Contact Ray Odde 612-222-8423

The Seneca waste treatment plant discharged an average of 24.0 cfs to the Minnesota River during July 1988.

Metropolitan Waste Control Commission - Savage Waste Treatment Plant

Contact: Ray Odde 612-222-8423

The average waste treatment plant discharged an average of 1.1 cfs to the Minnesota River during July 1988. This plant has been phased out, and wastewater from the Savage area is being treated at other MWCC plants.

Northern States Power Company - Black Dog Generating Plant

Contact: Dave Heberling

The Black Dog plant is a coal fired electrical generating plant that uses river water and an adjacent floodplain lake for cooling. River water is withdrawn, passed through the plant to cool condensers, and is discharged to Black Dog Lake, and water returns to the river through two water level control structures, one located upstream and one downstream of the plant.

The average rate of appropriation at the plant during July 1988 was 542 cfs. An estimated 1 cfs is consumptively used, lost to evaporation.

The combination of withdrawals and return flows in the lower Minnesota River, downstream of the Jordan gage total approximately 50 cfs. Minnesota River discharge to the Mississippi River at Fort Snelling, is approximately 50 cfs greater than the gaged discharge at Jordan, not counting any natural inflows, pumping from the Kramer quarry and airport runoff.

Effects of Appropriations and Return Flows on River Discharge

7. Water withdrawals, return flows, tributary inflows, dam operation, evaporation, storage in pools, storage in riverbank soils, and groundwater inflow all affect the quantity of water flowing the river channel. Table 2 is a rough water budget for the Mississippi River for the latter part of July 1988. Data on releases from dams were obtained from Corps of Engineers routine water control records for the headwaters dams, from provisional (uncorrected) records of the U.S. Geological Survey, and from

Minnesota Power. Data on July-August 1988 releases from the recently redeveloped at the time of the survey. The locations in table 2 are listed from upstream to downstream by river mile. All flow rates are in cubic feet per second.

The third column in table 2 lists the withdrawals in parentheses and return flows. Gaged Mississippi River discharges (gaged Q) are listed near the right side of the table. Computed river discharge is shown for each river mile segment between gaging stations, calculated from the upstream gaged discharge minus withdrawals plus return flows and gaged tributary inflows.

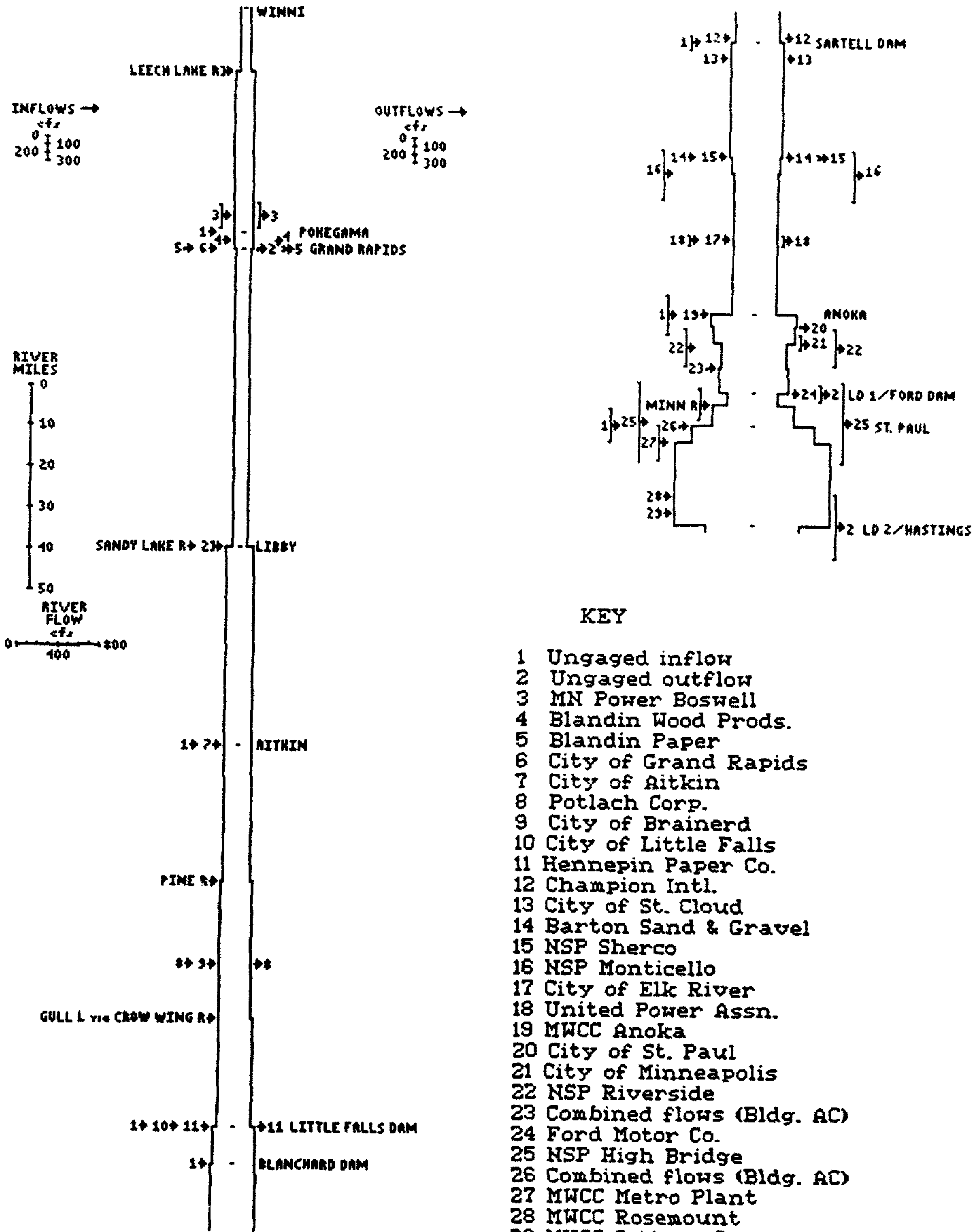
The ungaged inflows or outflows for each river segment between gaging stations are listed at the right side of table 2. These values were the differences between the calculated discharge for the river segment and the actual gaged discharge at the downstream gaging station. The values in the ungaged inflow/outflow column represent the combination of ungaged surface inflow from tributaries, groundwater discharge to the river, discharge from or to bank storage, change in pool storage, changes in discharge induced by dam operation, and inaccuracies introduced by stream gaging. Generally, during the latter part of July 1988 described, the ungaged inflows/outflows represent groundwater and tributary inflows plus discharge changes induced by dam operation.

Figure 2 is a graphic representation of the river water budget presented in Table 2 for July 30, 1988. The influence of withdrawals, return flows, and river regulation at dams is illustrated in the figure. Inflows are listed on the right of the vertical graph illustrating river discharge. Outflows are listed on the right. The vertical size of the brackets next to the numbered inflows and outflows is proportional to their flow rates. The length of the vertical graph illustrating the river is proportional to river miles and the width is proportional to river discharge. The two parts of the graph are continuous, separated only to accommodate page length.

The following narrative is provided to interpret Table 2 and Figure 2 and to discuss the influence of human activities on Mississippi River discharge during the July 1988 low flow period. The discussion of river discharge

TABLE 2. Water Budget for the Mississippi River Upstream of Lock and Dam 2 in 1988.

River	Loca-	Points of Inflows,	Inflows &	onsump-	Tributary Inflows						Computed Q						Gaged Q						Ungaged Inflow/(Outflow)					
Mile	tions	Return Flows & Withdrawals	Withdrawals	tive Use	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	01-Aug	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	01-Aug	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	01-Aug	27-Jul	28-Jul	29-Jul	30-Jul	31-Jul	01-Aug
561		MISSISSIPPI RIVER			101	101	101	101	101	101	101	101	101	101	101	101												
561	WINNI DAM										101	101	101	101	101	101	101	101	101	101	101	101	0	0	0	0	0	0
545		LEECH LAKE RIVER			106	104	104	102	104	102	207	205	205	203	205	203												
510		MN Power Boswell	(261.8)								(55)	(57)	(57)	(59)	(57)	(59)												
510		MN Power Boswell	244.7	(17.2)							190	188	188	186	188	186												
506	POKEGAMA DAM										200	200	200	200	200	200	200	200	200	200	200	200	10	12	12	14	12	14
504		Blandin Wood Prods.	(0.7)								199	199	199	199	199	199												
50..		Blandin Wood Prods.	0.1	(0.3)							199	199	199	199	199	199												
502		Blandin Paper	(60.7)								139	139	139	139	139	139												
502		Blandin Paper	42.6	(0.5)							181	181	181	181	181	181												
502	BLANDIN DAM										181	181	181	181	181	181												
502		City of Grand Rapids	17.8								199	199	199	199	199	199												
502	GRAND RAPIDS										163	165	169	162	140	148	163	165	169	162	140	148	(46)	(34)	(30)	(47)	(59)	(51)
430		SANDY LAKE RIVER			23	23	23	23	23	23	176	188	192	176	163	171												
430	LIBBY										288	283	270	268	276	276	288	283	270	268	276	276	112	95	78	93	113	105
382		City of Aitkin	0.5								289	284	271	269	277	277												
382	AITKIN										314	302	301	293	294	297	314	302	301	293	294	297	26	19	31	25	18	21
349		PINE			30	30	30	30	30	30	344	332	331	323	324	327												
329	BRAINERD										344	332	331	323	324	327												
329		Potlach Corp.	(4.7)								339	327	326	318	319	322												
329		Potlach Corp.	4.5	(0.2)							344	332	331	323	324	327												
329		City of Brainerd	3.7								348	336	335	327	328	331												
316		GULL (via CROW WING RIVER)			18	18	18	18	18	18	366	354	353	345	346	349												
290	LITTLE FALLS DAM										527	517	509	425	604	747	527	517	509	425	604	747	162	164	157	61	259	399
290		City of Little Falls	1.0								528	518	510	426	605	748												
290		Hennepin Paper Co.	(2.7)								525	515	507	423	602	745												
290		Hennepin Paper Co.	2.3	(0.4)							528	518	510	426	605	748												
281	BLANCHARD DAM										484	484	509	435	813	835	484	484	509	435	813	835	(44)	(34)	(1)	9	208	87
258		Champion Intl.	(18.0)								466	466	491	417	795	817												
258		Champion Intl.	17.1	(0.9)							483	483	508	434	812	834												
257	SARTELL DAM										353	354	469	508	819	969	353	354	469	508	819	969	(130)	(129)	(39)	74	7	135
253		City of St. Cloud	(14.0)								339	340	455	494	805	955												
253		City of St. Cloud	10.9								350	351	466	505	816	966												
253	ST. CLOUD DAM										350	351	466	505	816	966												
229		Barton Sand & Gravel	(1.3)								349	350	465	504	815	965												
229		Barton Sand & Gravel	1.3								350	351	466	505	816	966												
229		NSP Sherco	(55.0)								295	296	411	450	761	911												
229		NSP Sherco	17.0	(38.0)							312	313	428	467	778	928												
225		NSP Monticello	(265.0)								47	48	163	202	513	663												
225		NSP Monticello	255.0	(10.0)							302	303	418	457	768	918												
209	ELK RIVER										302	303	418	457	768	918												
209		City of Elk River	0.7								303	304	419	458	769	919												
209		United Power Assn.	(111.5)								191	192	307	346	657	807												
209		United Power Assn.	111.5								303	304	419	458	769	919												
191	ANOKA GAGE										931	900	868	842	856	869	931	900	868	842	856	869	628	596	449	384	87	(50)
191		MWCC Anoka	3.5								935	904	872	846	860	873												
191	COON RAPIDS DAM										935	904	872	846	860	873												
185		City of St. Paul	(35.0)								900	869	837	811	825	838												
184		City of Minneapolis	(167.0)								733	702	670	644	658	671												
183		NSP Riverside	(376.0)								357	326	294	268	282	295												
183		NSP Riverside	376.0	(1.0)							732	701	669	643	657	670												
178		Combined flows (bldg. AC)	43.9								776	744	712	686	700	713												
178	ST. ANTHONY FALLS										776	744	712	686	700	713												
172		Ford Motor Co	(1.3)	(1.0)							774	743	711	685	699	712												
172	L/D 1 FORD DAM										430	500	530	500	300	410	430	500	530	500	300	410	(344)	(243)	(181)	(185)	(399)	(302)
169		MINNESOTA RIVER			336	326	318	313	311	304	766	826	848	813	611	714												
165		NSP High Bridge	(401.0)								365	425	447	412	210	313												
165		NSP High Bridge	400.0	(0)							765	825	847	812	610	713												
164		Combined flows (bldg. AC)	32.8								798	858	880	845	643	746												
164	ST. PAUL										1,140	1,180	1,110	1,180	1,170	1,060	1,140	1,180	1,110	1,180	1,170	1,060	343	323	231	336	528	315
160		MWCC Metro Plant	352.0								1,492	1,532	1,462	1,532	1,522	1,412												
147		MWCC Rosemount	0.7								1,493	1,533	1,463	1,533	1,523	1,413												
143		MWCC Cottage Grove	2.2								1,49[illegible]	[illegible]85	1,465	1,535	1,525	1,415												
140	U[illegible]INGS										1,400	[illegible]	1,100	900	900	500	1,400	1,400	1,100	900	900	500	(95)	(135)	(3[illegible]	[illegible]5)	(625)	(915)



KEY

1 Ungaged inflow
2 Ungaged outflow
3 MN Power Boswell
4 Blandin Wood Prods.
5 Blandin Paper
6 City of Grand Rapids
7 City of Aitkin
8 Potlach Corp.
9 City of Brainerd
10 City of Little Falls
11 Hennepin Paper Co.
12 Champion Intl.
13 City of St. Cloud
14 Barton Sand & Gravel
15 NSP Sherco
16 NSP Monticello
17 City of Elk River
18 United Power Assn.
19 MWCC Anoka
20 City of St. Paul
21 City of Minneapolis
22 NSP Riverside
23 Combined flows (Bldg. AC)
24 Ford Motor Co.
25 NSP High Bridge
26 Combined flows (Bldg. AC)
27 MWCC Metro Plant
28 MWCC Rosemount
29 MWCC Cottage Grove

FIGURE 2. Mississippi River Water Budget: Winnibigoshish Dam to Lock and Dam 2, July 30, 1988.

does not include an analysis of travel time, change in channel and reservoir storage, evaporation and bank storage, which are relative unknowns. The river discharge values presented in table 2 and the following discussion are daily averages for the dates reported, and are not "lagged" to reflect travel time of a parcel of water.

Starting at Lake Winnibigoshish Dam, the Corps of Engineers was releasing a continuous routine low flow of 101 cfs. At river mile 545, routine low flow releases from Leech Lake via the Leech Lake River contributed an additional 102 cfs. The Minnesota Power Clay Boswell generating plant consumptively used 17.2 cfs. Ungaged inflow between Winnibigoshish Dam and Pokegama Dam contributed an additional 14 cfs, probably from groundwater inflow to the river.

In the Grand Rapids area, consumptive industrial and municipal uses were largely offset by discharges through the municipal treatment plant that originated from wells, resulting in a net decrease in river discharge of 0.9 cfs. Operation of Pokegama Dam was constant with a release of 200 cfs. Operation of Blandin Dam, however, involved storage of water in the pool during the last few days in July, resulting in a decrease in river discharge below the dam of 47 cfs on July 30.

At river mile 430, routine low flow releases from the Corps-operated sandy Lake Dam contributed 23 cfs via the Sandy Lake River. Ungaged inflows between Blandin Dam at Grand Rapids and the Libby gage added 93 cfs to the river flow.

Between the Libby gage at river mile 430 and the Aitkin gage at river mile 382, ungaged inflows contributed 25 cfs on July 30. Wastewater discharge at the City of Aitkin added 0.5 cfs.

Routine low flow release from the Corps-operated Pine River Dam added 30 cfs to the Mississippi River at river mile 349 via the Pine River.

At the City of Brainerd, municipal and industrial discharges of well water resulted in a net increase in river discharge of 3.5 cfs.

At river mile 316, routine low flow releases from the Corps-operated Gull Lake Dam added 18 cfs via the Gull Lake River. On July 30, 1988, routine low flow releases from the six headwaters reservoirs totaled 271 cfs.

Uses of water by the city of Little Falls and the Hennepin Paper mill resulted in an increase in river discharge of 0.6 cfs in the Little Falls area.

Releases from the Blanchard Dam operated by Minnesota Power were 435 cfs on July 30. Ungaged inflow was 9 cfs between Little Falls and Blanchard Dams.

Consumptive use of water at the Champion Paper plant was 0.9 cfs. Champion Paper was releasing 508 cfs from the Sartell Dam on July 30. The corresponding ungaged inflow between Blanchard Dam and Sartell Dam was 74 cfs.

The City of St. Cloud consumptively used 3.1 cfs.

The NSP Monticello and Sherco power plants consumptively used a total of 48 cfs.

Ungaged inflows between the Sartell Dam and the Anoka gage were substantial, 384 cfs on July 30.

Withdrawals for municipal water supply for Minneapolis and St. Paul totaled 202 cfs.

Metropolitan consumptive uses of water for the Ford plant and the two NSP power plants were minor, totaling 3.0 cfs. Return flows of groundwater pumped for building air conditioning in the metro area are estimated to have contributed 76.4 cfs.

The Minnesota River added approximately 313 cfs, and the return flows from the MWCC treatment plants contributed an additional 354.9 cfs to Pool 2 of the Mississippi River.

Effects of Dam Operation on River Discharge

8. There are 12 water control structures operated by 8 different owners on the Mississippi River between and including Winnibigoshish Dam and Lock and Dam 2 (table 3).

Table 3. Main Stem dams on the Mississippi River, Minnesota River, miles 140-561.

Name of Dam	River Mile	Owner	Type of Dam
Winnibigoshish	561	Corps of Engineers	headwater reservoir
Pokegama	506	Corps of Engineers	headwater reservoir
Blandin	502	Blandin Paper	hydro
Little Falls	290	Minnesota Power	hydro
Blanchard	281	Minnesota Power	hydro
Sartell	257	Champion Paper	hydro
St. Cloud	253	City of St. Cloud	hydro
Coon Rapids	191	Hennepin County	abandoned hydro
Upper St. Anthony	178	Corps/NSP	navigation/hydro
Lower St. Anthony	178	Corps/NSP	navigation/hydro
Lock and Dam 1	172	Corps/Ford Motor	navigation/hydro
Lock and Dam 2	140	Corps of Engineers	navigation/hydro

Daily operation of these dams is informally coordinated by exchange of information between operators, using data on daily releases from the dams, pool elevations behind the dams, and with data provided by the U.S. Geological Survey and the Corps of Engineers gaging systems. Each dam has a specific operating strategy. Owners of the hydropower dams have licenses to operate issued by the Federal Energy Regulatory Commission (FERC). Water control plans for the hydropower dams are specified in the FERC licenses. Operating strategy for the Corps dams is contained in the water control manuals for the projects.

During periods of normal river discharge, daily changes in gate settings or hydropower turbine operation at the various dams do not produce large relative changes in river discharge. During periods of low flow, however,

changes in gage setting can produce large percentage changes in river discharge.

Table 4 provides the flow data for daily average releases from Mississippi River dams during the 1989 low flow period. Figures 3 and 4 illustrate the influence of dam operation on Mississippi River discharge over the course of six days at the end of July 1988.

Releases from the hydropower dams varied during the low flow period during the summer of 1988 as the dam operators regulated for hydropower production and maintenance of pool elevations behind the dams. The result was that artificially-induced short-term increases and decreases in river discharge occurred that, as a percentage of river discharge, were significant. For example, releases from the Minnesota Power Little Falls dam were reduced from 527 cfs on July 25 to 431 cfs on July 26 (table 4). At the Blanchard Dam, releases were reduced from 610 cfs on July 24 to 390 cfs the next day. Champion Paper increased releases from the dam at Sartell from 354 cfs on July 28 to 469 cfs on July 29. This kind cf dam operation produces "slugs" and "gaps" in river discharge that are routed downstream (figures 3 and 4, causing problems for downstream water users and other dam operators during periods of low river discharge.

Changes in river discharge that constitute a large percentage change over a short time during a period of extreme low flow can cause significant disruptions to downstream aquatic habitat, water uses that are discharge-sensitive such as power production at the large NSP power plants, and downstream dam operation. there is a clear need for more coordinated operation of main stem Mississippi River dams during future low flow periods. Rather than hydro dam operators targeting reservoir stages and maximal hydropower production during periods of extreme low flow, it would be in the public interest to have coordinated operation of the river system with a target of maintenance of a more even rate of river discharge.

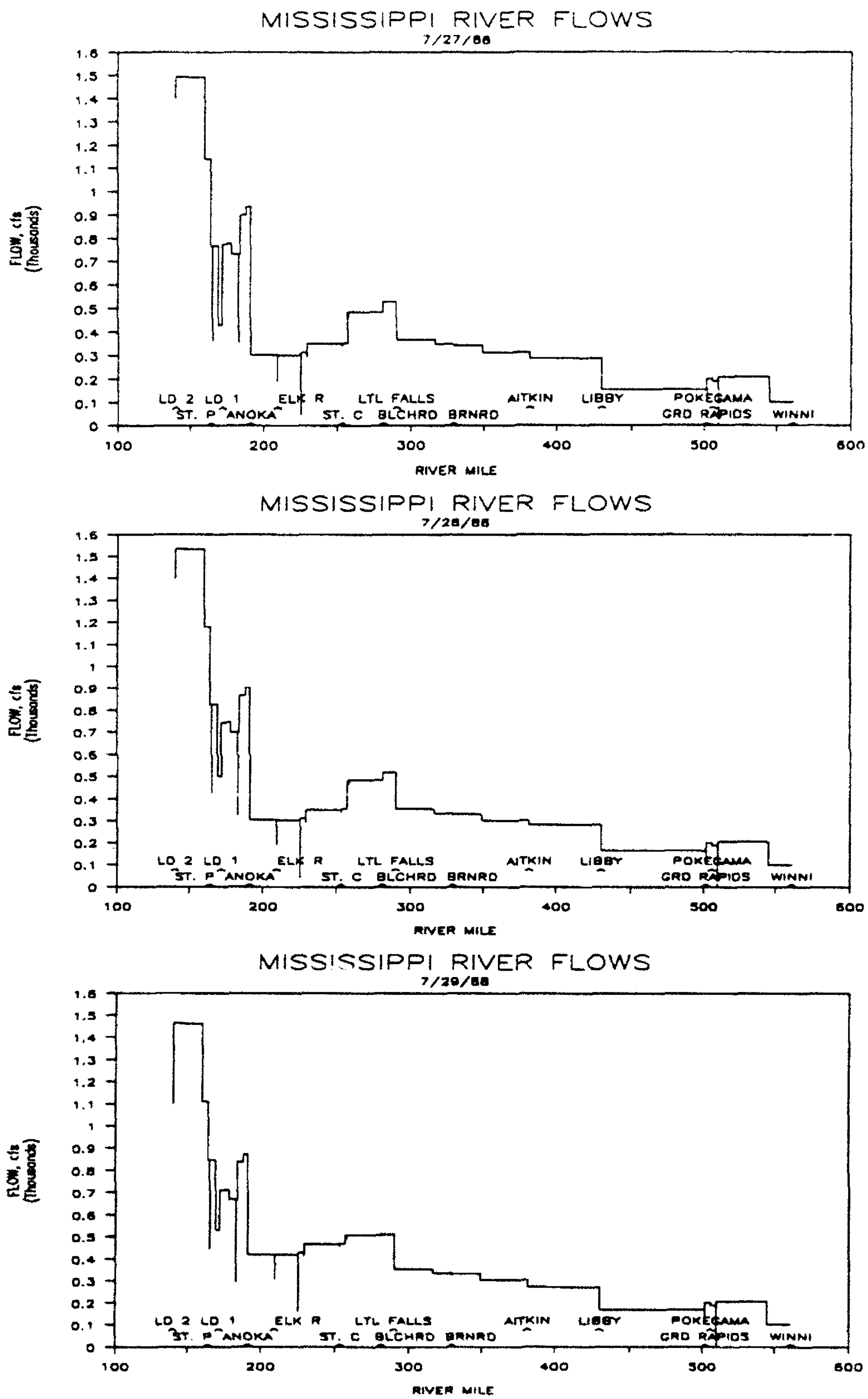


FIGURE 3. Mississippi River Discharge by River Mile on July 27, 28 and 29, 1988.

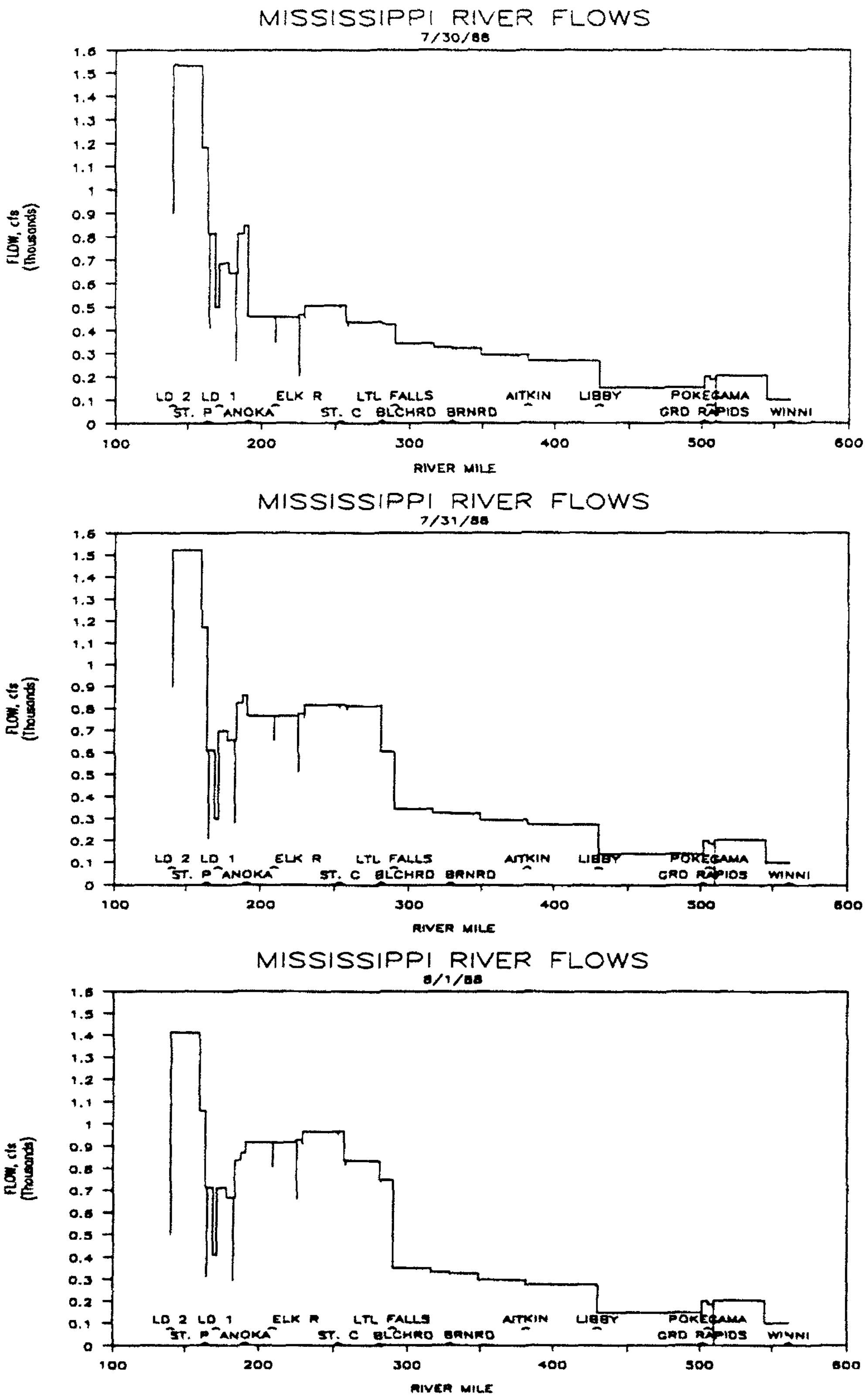


FIGURE 4. Mississippi River Discharge by River Mile July 30, 31, and August 1, 1988.

APPENDIX D

AGENCY COORDINATION MATRIX

PUBLIC INFORMATION PLAN

IN-HOUSE DROUGHT MANAGEMENT TEAM

APPENDIX D

AGENCY COORDINATION MATRIX
PUBLIC INFORMATION PLAN
IN-HOUSE DROUGHT MANAGEMENT TEAM

INTRODUCTION

The following two sections describe the St. Paul District's organizational configuration for drought management and the nature and extent of interagency coordination and public involvement during low flow conditions.

DROUGHT MANAGEMENT TEAM

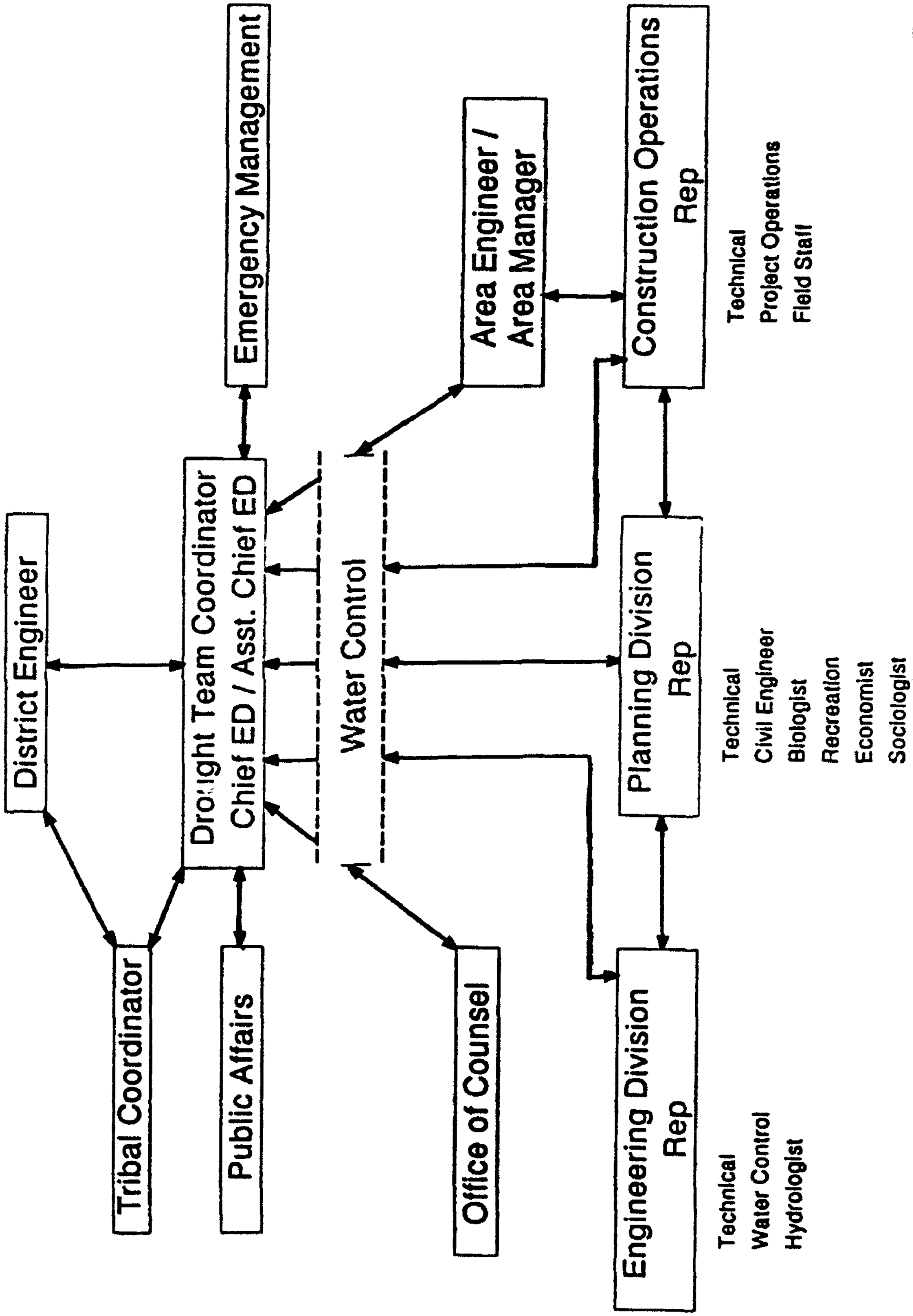
STRUCTURE: The organizational structure of the drought management team is depicted on figure D-1. The nucleus of the team consists of the District Engineer, Drought Team Coordinator, Public Affairs Office, Office of the Counsel, Emergency Management Office, Area Engineer/Area Manager, Tribal Coordinator and Division Representatives. The technical component of the team is comprised of interdisciplinary team members having expertise regarding the various aspects of the resource base and human interaction with the resource.

Under normal conditions, Water Control assumes the duties of Drought Team Coordinator (DTC). When drought watch conditions exist and the District Engineer elects to intensify District involvement, the Chief of Engineering Division or the Assistant Chief, Engineering Division, assumes the role of Drought Team Coordinator. Division representatives are appointed by their respective Division Chiefs. District Office representatives are appointed by their chiefs, and technical personnel are assigned by their Branch and Section Chiefs.

FUNCTION: The team has two primary functions. The first is to provide the District Engineer with the requisite information for decision-making regarding deviation from routine reservoir operating procedures. The decision-making process is summarized in the section following the Executive Summary at the beginning of this report. The second function is

FIGURE D-1

ST. PAUL DISTRICT
DROUGHT MANAGEMENT TEAM
ORGANIZATIONAL COORDINATION NETWORK



to provide other agencies, communities, special interest groups, and the general public with accurate information regarding Corps of Engineers responsibilities and the condition of the resource.

PROCESS: To carry out the primary functions in a timely, efficient, and effective manner, the drought team adheres to the six-step planning process: Identification of problems and opportunities; Inventory and forecast; Formulation of alternatives; Evaluation Assessment of alternatives; Comparison of alternatives; Selection of Recommended alternative.

DIVISION OF LABOR AND RESPONSIBILITIES: Each drought team element has specific tasks and activities related to the overall team functions.

Drought Team Coordinator: Under normal conditions, the Drought Team Coordinator serves as the District's primary point of contact for drought related matters. In this capacity, the DTC is responsible for:

- Maintaining a current information base regarding drought related activities.

- Coordinating with other Federal, State, and local agencies as well as other entities regarding their drought initiatives.

- Attending spring snowmelt coordination meeting.

- Developing opportunities and coordinating training for drought team members.

When drought conditions exist, the DTC is responsible for:

- Implementing the stepped agency coordination matrix.

- Providing overall direction to the drought team.

- Facilitating information flow to and from the District Engineer.

- Serving as the District's primary spokesperson.

Public Affairs Office

- Makes recommendations to the DTC regarding implementation of the public information plan.

- Monitors media reports.

- Maintains mailing lists.

Office of Counsel:

- Ensures that the District processes and actions do not conflict with State, Federal, and Tribal law.

Emergency Management:

- Coordinates upward reporting of drought status.

- Coordinates Public Law 99 water supply requests.

- Serves as the repository for all incoming drought related correspondence, to support the upward reporting duties.

Area Engineer/Area Manager:

- As requested by the DTC, serves as the District representative.

- Provides area information and technical data as requested by the study team.

- As requested by the DTC, participates in agency coordination meetings.

Tribal Coordinator:

- Provides overall direction concerning coordination and consultation with reorganized Chippewa Tribal Governing bodies.

Division Representative:

- Coordinates with other agency counterparts, as requested by the DTC.

- Coordinates the assignment of Division technical personnel to the study team.

- Coordinates and reviews Division technical input.

Technical Personnel:

- Provide accurate and adequate technical information in sufficient detail to ensure compliance with District responsibilities.

- Make suggestions regarding ways to improve information quality and information flow.

- Remain current regarding technical innovation and resource conditions.

- Coordinate with other agency technical personnel, as requested by the DTC.

INTERNAL REPORTING AND INFORMATION FLOW: Established organizational communication channels are suspended for drought team members during low flow conditions. Unless otherwise stipulated by the District Engineer or the Drought Team Coordinator, all technical information flows to the Drought Team Coordinator through the division representative. Public Affairs, Office of Counsel, Emergency Management, and Area Engineer information flows directly to the Drought Team Coordinator. The Drought Team Coordinator reports directly to the District Engineer. The Drought Team Coordinator provides information to technical team members through respective division representatives.

All drought team personnel are responsible for providing written documentation of phone conversations and meetings held with personnel from outside the organization. This information is transmitted directly to the drought team coordinator.

INTERAGENCY COORDINATION AND PUBLIC INFORMATION:

GENERAL CONSIDERATIONS Several public laws, executive orders, and engineering regulations provide guidance for interagency coordination and public information programs. Although this guidance has been developed primarily for Corps of Engineer Civil Works programs, the basic tenets are directly applicable to emergency conditions such as drought. Interagency coordination and public information programs provide opportunities for participate decision-making and enable exchange of information to and from other agencies and the general public.

The primary purpose of interagency coordination and public information is to ensure that Corps of Engineers planning efforts, programs, and activities are responsible to the needs and concerns of other agencies, groups, and the general public. Important objectives include providing for consultation with other agencies and Chippewa Tribal governments to ensure that their needs and concerns are incorporated into the decision-making process and to provide information regarding the Corps of Engineers authroity, responsibilities, and procedures. In addition, interagencies coordiantion and public information programs are a basic feature of democratic practices and responsibility, constitute good management practices, and are excellent tools for conflict managment and resolution.

LOW FLOW COORDINATION AND PUBLIC INFORMATION The Drought Response Matrix, Figure D-2, provides a description of drought phases and and actions that can be taken by State and Federal agencies, public water suppliers, industrial users, and agricultural and self-supplied interests. In addition to the activities listed in column 2, the Corps of Engineers will have for each drought phase a corresponding coordination component, public information/involvement component, and a study process component.

FIGURE D-2

Agency Drought Coordination Matrix

Condition and Program Phase	State and Federal Actions	Local Actions: Public Water Suppliers	Local Actions: Industrial	Local Actions: Agricultural and Private
<u>NORMAL CONDITIONS:</u> *Water quantity is adequate for normal purposes; water quality is acceptable under normal management. *Normal releases from reservoirs. *Normal precip./weather patterns/Hydrologic conditions	*Develop precipitation, streamflow, ground water, and water quality monitoring programs. *Conduct state and regional water studies and coordinate recommended actions. *Assist public water suppliers and local government in developing emergency water management plans. *Establish public education program. *Emergency planning is needed in a generic sense.	*Develop Emergency Water Management Plans. *Develop additional storage and treatment facilities; evaluate distribution system. *Adopt standby rates, other necessary ordinances and codes, and establish mutual aid agreements, interconnections, conservation education, etc.	*Develop Individual Emergency Water Management Plans. *Develop additional wastewater storage. *Develop alternative water storage, and conservation measures. *Purchase standby equipment and install permanent equipment as necessary for recycling.	*Develop emergency water management plans. *Evaluate need for irrigation. *Enlarge pons, purchase tanks, drill wells, install conservation devices and livestock watering tanks, etc. *Evaluate agricultural water use and find where conservation could be used. *Evaluate domestic water use and install water-saving devices, etc., reduce stress on supply source.
<u>DROUGHT WATCH:</u> *Lower than normal precipitation, declining streamflows and groundwater levels. *Palmer Index, Frost, Reservoir and lake levels, snow/water content, streamflow, groundwater condition result in a 30, 60, 90 day outlook that is deficient.	*"Drought task force" initial meeting (see agency list). *Intensify selected monitoring activities. *State initiates an awareness program via media, etc.	*Monitor water sources and daily water use for specific purposes and anticipate user demand. *Monitor potential conflicts and problems.	*Monitor water source and daily water use for specific purpose and anticipated demand. *Monitor water quality.	*Monitor water sources and daily water use for specific purposes and anticipate demand.
<u>CONSERVATION PHASE: 1000 cfs</u> *Water quantities/water quality deteriorating or conflicts among users. *Agency/utilities appeal to public for voluntary conservation. *Public awareness program. *Closely monitor drought indicators. *Monitor NWSs 30, 60, 90 day weather and precipitation projections. *Monitor NWS streamflow projections.	*More frequent "task force" meetings to exchange water supply and water quality data and discuss actions. *Monitor systems and users having past problems and monitor plan implementation. *Respond to local and individual appeals for assistance. *State agencies issue orders to water suppliers and/or dischargers. *Public information about conditions. *Public water conservation education/encourage.	*Implement "conservation" phase at plan triggering point. Potential conservation measures include curtailment of outside uses, education, and pricing. *If conservation goal is not obtained, implement restrictions. *Notify MDNR of source conflicts.	*Institute re-cycling cut-back production, store wastewater, alter production schedule per emergency industrial water management plan during a drought. *Notify MDNR of source conflicts.	*Continue conservation of domestic supplies *Notify MDNR of source conflicts. *Implement water conservation measures for agricultural uses.
<u>RESTRICTION PHASE: 750 cfs</u> *Insufficient supplies to meet all demands. *Allocation suspensions taking place. *Continued decline in water supply and/or water quality. *Utilize drought indicators. *Utilize NWS 30, 60, 90 day weather and precipitation projections. *Closely monitor NWS streamflow projections.	*Same responses as in Conservation Phase and State implements mandatory restrictions. *State Contingency Actions accomplished (example: ease NSP thermal permit). *Consider emergency releases from reservoirs above the low flow plans.	*Implement "restrictions" phase at plan triggering point. Restrictions could include banning of some outdoor water uses, per capita quotas, cut-backs to non-residential users. *Notify MDNR of source conflicts.	*Institute additional cut-backs in production, storage of wastewater, or changes in production schedule, etc., per emergency industrial mgmt plan or Commissioner's orders for suspensions. *Notify MDNR of conflicts.	*Same responses as in Conservation Phase. *Follow MDNR allocation restrictions on irrigation.
<u>EMERGENCY PHASE: 554 cfs</u> *Severe water supply or water quality problems *Highest priority water supplies not being met. *Threatened or actual power "brownouts". *MAPP (NSP power pool) resources threatened. Strict monitoring of drought indicators. *Strict monitoring of weather and streamflow projections.	*Governor responds to critical situations by declaring an emergency. *MDEM implements emergency operations plan. *State age3ncy mediates conflicts. *Consider Corps PL-99 authorities. *Implement emergency releases from reservoirs above low flow plans.	*Provide bottled water and sanitation supplies to users. *Make hospitals, firefighting, etc., priority. *Initiate hauling of water. *Comply with State Commissioner's Orders.	*Comply with Governor's Emergency Declarations. *Coordinate emergency action with local government. *Implement hauling water for sanitation, domestic uses.	*Request local government assistance in obtaining water for domestic purposes, and in supporting livestock. *Implement hauling water, etc., in cooperation with local governments.

NORMAL CONDITIONS: Normal conditions are depicted by adequate water supply and acceptable water quality. Operation of the Headwaters Reservoir System is guided by standard operating procedures.

Coordination: When authorized by Congress, coordinate State and regional water studies and recommended actions. Provide technical assistance to public water suppliers and local governments for emergency water planning. Attend spring snowmelt meeting. Update low flow plan, as needed.

Public Information: Develop and coordinate Headwaters educational video and brochure. At a minimum, these educational materials will include the history of the reservoir system, Congressional authorization and Corps of Engineers responsibilities, and current uses and operation, including the routine low flow operation and objectives. Institutionalize Headwaters newsletter.

Study Process Component: Training. Provide training to the District Drought Management Team regarding all aspects of drought contingency planning.

DROUGHT WATCH PHASE: Characterized by lower than normal precipitation and declining streamflows and groundwater levels. Drought indicators predict a 30-, 60-, and 90-day forecast that is deficient.

Coordination: Drought team coordinator and selected team members participate in initial State Drought Task Force meeting. Task force membership is displayed in figure 3. Drought Team Coordinator should notify BIA and Chippewa Tribal representatives of the Drought Task Force meeting.

Conduct initial consultation with Chippewa Tribal government representatives.

Conduct initial consultation with Minnesota Department of Natural Resources/Division of Waters.

Public Information: Press release targeted at Twin Cities and Headwaters area residents. "Press releases should be FAXED to Congressional offices,

FIGURE D-3

1988 Drought Task Force Members

Ron Nargang	DNR-Waters	296-4810
Ken Reed	DNR-Waters	296-4806
Jim Zandlo	State Climatology/DNR-Waters	296-4214
Dave Ford	DNR-Waters	296-0437
Roger Holmes	DNR-Section of Wildlife	296-3344
George Meadows	DNR-Forestry	296-4490
Bill Clapp	Attorney General's Office	296-0686
Carroll Rock	USDA, Ag Statistician, 149 Ag. Bldg., 90 W. Plato Blvd.	296-3896
Tom Rulland	State Planning	296-2319
Gary Englund	Health Department	623-5330
Pat Bloomgren	Health Department	623-5297
Darryl Anderson	Mn/DOT, Env. Serv., 704 Trans. Bldg.	296-8530
Pat Motherway	Dept. of Agriculture, 311 Ag. Bldg, 90 W. Plato Blvd.	297-1551
Don Friedrich	ASCS-Farm Credit Bldg., 375 Jackson St., Room 400, St. Paul, MN 55101	290-3651
David Lundberg	Emergency Management, B5 Capitol	296-0463
Lloyd Lund	Emergency Management, B5 Capitol	296-0451
Perry Smith	Minneapolis Public Works, 203 City Hall, Minneapolis, MN 55415	348-2243
Jim F. Hayek	Minneapolis Public Works, 203 City Hall, Minneapolis, MN 55415	348-2418
Verne Jacobson	St. Paul Public Works, 25 W. 4th St., 4th Fl., City Hall Annex, St. Paul, MN 55415	298-4166
Roger Goswitz	St. Paul Public Works, 25 W. 4th St., 4th Fl., City Hall Annex, St. Paul, MN 55415	298-4166
Herb Nelson	Corps of Engineers, 1421 USPO & Custom House, St. Paul, MN 55101-1479	220-0403
Jim Campbell	National Weather Service, Fed. Aviation Bldg., Room 302, 6301 34th Ave. S., Mpls, MN 55450	725-3400
Gary McDevitt	National Weather Service, Fed. Aviation Bldg., Room 302, 6301 34th Ave. S., Mpls, MN 55450	725-3400
Pat Neuman	National Weather Service-River Forecast Ctr., Fed. Aviation Bldg., Room 202, 6301 34th Ave. S., Mpls, MN 55450	725-3090
Dean Braatz	National Weather Service-River Forecast Ctr., Fed. Aviation Bldg., Room 202, 6301 34th Ave. S., Mpls, MN 55450	725-3090
Kurt Gunard George Carlson	U.S. Geological Survey, 702 USPO & Custom House, St. Paul, MN 55101	229-2624
Mark Seeley	Ag. Extension/U of M	625-4724
Stan Kumpula	Corps of Engineers, 1421 USPO & Custom House, St. Paul, MN 55101-1479	220-0304
Jim Birkholtz	Dept. of Ag./Board of Water & Soil Res.	296-2767
Arnold Newes	MN Hospitality Assoc., 871 Jefferson Ave., St. Paul, MN 55102	222-7401
Roger Schweiters	MN Resort Assoc., Boyd Lodge, HCR-1, Box 286, Crosslake, MN 56442	218-543-4125
Dave Heberling	NSP, 414 Nicollet Mall, Mpls, MN 55401	330-1925
Gary Oberts	Metropolitan Council	291-6359

an appropriate amount of time before they are released to the media and the general public".

Letter to appropriate State Senators and Representatives and U.S. Senators and Representatives.

The press release and letters will summarize activities to data and future involvement.

Project condition information to the Minnesota Office of Tourism.

<u>Study Process Component</u>: Initiate problem identification and update inventory and assessment of resource base and use.

CONSERVATION PHASE: Characterized by a deterioration in water quality and water supplies. Conflicts among users may develop.

<u>Coordination</u>: Team members coordinate with counterparts in other State and Federal agencies, local governments, industry, and Chippewa Tribal Resource Managers to exchange information and obtain necessary data.

Coordinate appeals for assistance that are consistent with Corps authority.

<u>Public Information</u>: District Engineer and designated team members hold press conference in District Office and Headwaters area. Congressional representatives should be notified of press conferences, as appropriate.

<u>Study Process Component</u>: Complete inventory and assessment of resource base and use. Begin alternative development.

RESTRICTION PHASE: Characterized by continued decline in water supply and water quality. Insufficient supply to meet all demands. State reviewing allocation permits.

<u>Coordination</u>: More intensive coordination for exchange of information and data collection. Alternative prioritization through coordination.

<u>Public Information</u>: Press release. FAX press releases to Congressional representatives prior to the conference.

Study Process Component: Complete analysis of alternative emergency discharge plans and make recommendation to District Engineer. Implement when directed by District Engineer.

PROTRACTED LOW FLOW

During periods of extended drought, local and regional priorities and problems may become overshadowed by National priorities and problems. Under these circumstances, U.S. Army Corps of Engineers actions may be directed by Congress or by existing U.S. Army Corps of Engineers Emergency Water Planning authorities administered at Washington level Secretary of the Army and Corps of Engineers Headquarters.

FUNDING FOR IMPLEMENTATION OF CONCLUSIONS

This appendix contains conclusions concerning the desirability of obtaining and developing additional information related to the Headwaters lakes project. The information that is described in each conclusion of this appendix would enhance the decision-making for water control for the project. However, the work items that are described in each conclusion will be scheduled, only as the availability of funding permits and in accordance with District priorities.

APPENDIX E

INSTREAM FLOW NEEDS

FOR THE UPPER MISSISSIPPI RIVER

INSTREAM FLOW NEEDS
FOR THE UPPER MISSISSIPPI RIVER

Introduction

1.0 The amount and quality of riverine habitat are greatly affected by river discharge. Habitat conditions such as total volume, wetted area of substrate, current velocity, water depth, water temperature, and water quality are all directly influenced by river discharge. All forms of riverine life and human recreational use of the river are affected by these discharge-related habitat conditions.

1.1 The Upper Mississippi River is a nationally-renowned stream, with good water quality and high-quality habitat that supports abundant aquatic life, a popular sport fishery, and considerable recreational use.

1.2 Operation of dams on the Mississippi River headwaters lakes imposes a regulated discharge regime on the river, primarily affecting streamflow by attenuating flood peaks and by augmenting low flows. This analysis addresses only the effects of low flow operation on riverine habitat conditions.

Study Objectives

1.3 The primary objective of this analysis is to evaluate the routine low flow rate of release from the Mississippi River headwaters lakes to determine its adequacy under normal conditions. The second objective is to evaluate the adequacy of the existing headwaters operating plan for maintaining riverine life during drought.

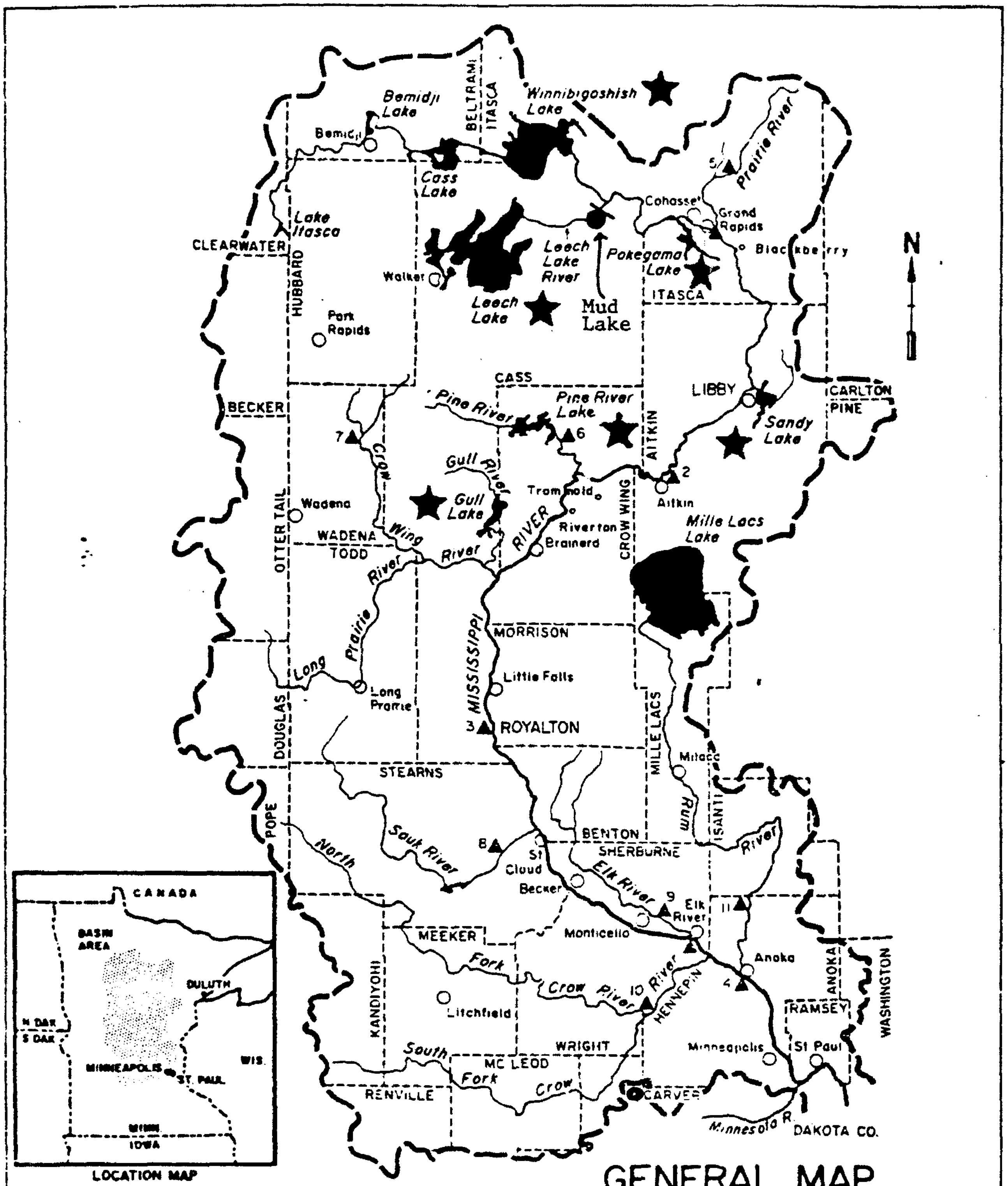
Study Reach of River

1.4 The reach of Mississippi River under consideration extends 421 miles from Lake Winnibigoshish Dam in north central Minnesota downstream through the Minneapolis-St. Paul metropolitan area, to Lock and Dam 2 near Hastings, Minnesota (figure E-1). River discharge upstream of Winnibigoshish Dam is not affected by Corps of Engineers operation of headwaters lakes. Four miles downstream of Lock and Dam 2 is the confluence with the St. Croix River, below which releases from the headwaters lakes contribute only a small fraction of total river discharge, even at extreme low flow. Mississippi River tributaries affected by Corps operation of the headwaters lakes are the Pine, Gull, and Leech Lake Rivers.

River Morphology

1.5 The Mississippi River varies in size from an average annual discharge of 522 cfs at Winnibigoshish Dam to 10,053 cfs at St. Paul (table E-1). The river varies considerably in gradient (figure E-2) and in geomorphic form.

1.6 Much of the upstream reach of the river has rock rubble substrate derived from glacial drift deposits. In some of the upstream reaches, the river meanders through bog, with organic materials in the banks and a sandy bed. The reach near Aitkin, Minnesota, is meandering with low gradient, a "u"-shaped channel, and with cut banks of clayey soil. There are many abandoned channel lakes and embayments in this reach of river. The river gradient increases considerably downstream of Brainerd, Minnesota flowing through rock outcroppings. From St. Cloud, Minnesota to the Twin Cities metropolitan area, the river flows through alluvial glacial deposits, with



LEGEND

Corps Dams

3 ▲ STREAMFLOW GAGING STATIONS

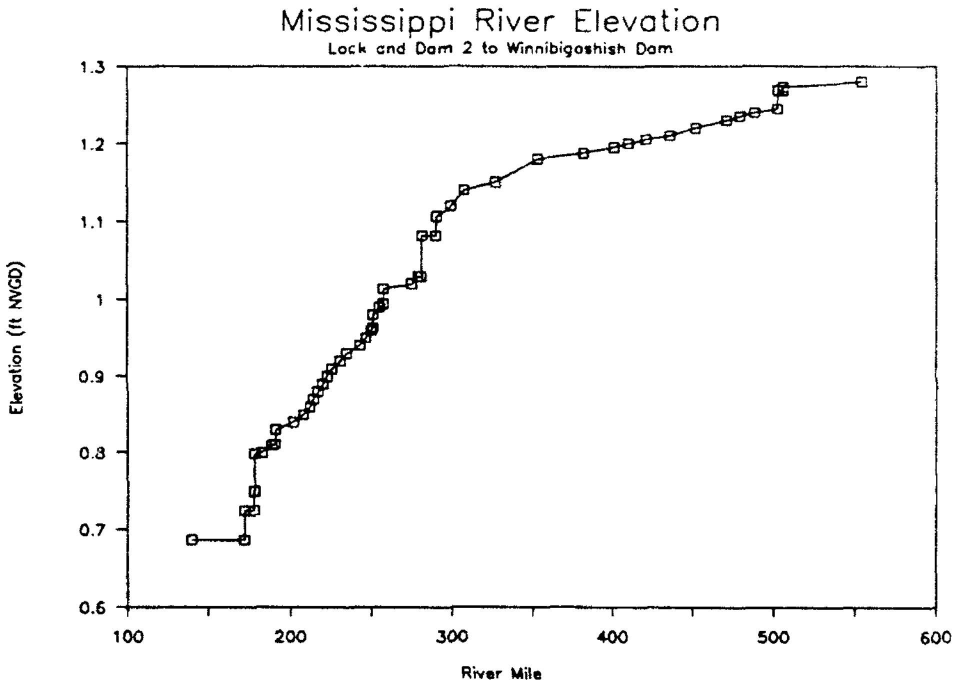
0 10 20 30
SCALE IN MILES

GENERAL MAP
UPPER MISSISSIPPI RIVER BASIN ABOVE THE MINNESOTA RIVER

Figure E-1

Table E-1. Discharge characteristics of the Upper Mississippi River

River Mile	Gage	Years of Record	Average Q (cfs)	Minimum Q (cfs)	Maximum Q (cfs)	Drainage Area (sq. miles)	Inches Runoff (per sq. mile)
561	Winni Dam	102	522	0	4370	1142	6.20
502	Grand Rapids	103	1192	0	12500	3370	4.80
430	Libby	56	2099	83	16000	5060	5.63
302	Aitkin	41	2971	151	20000	6140	6.57
281	Royalton	62	4638	254	37700	11600	5.43
191	Anoka	55	8019	529	91000	19100	5.70
164	St. Paul	88	11233	632	100000	36800	4.14



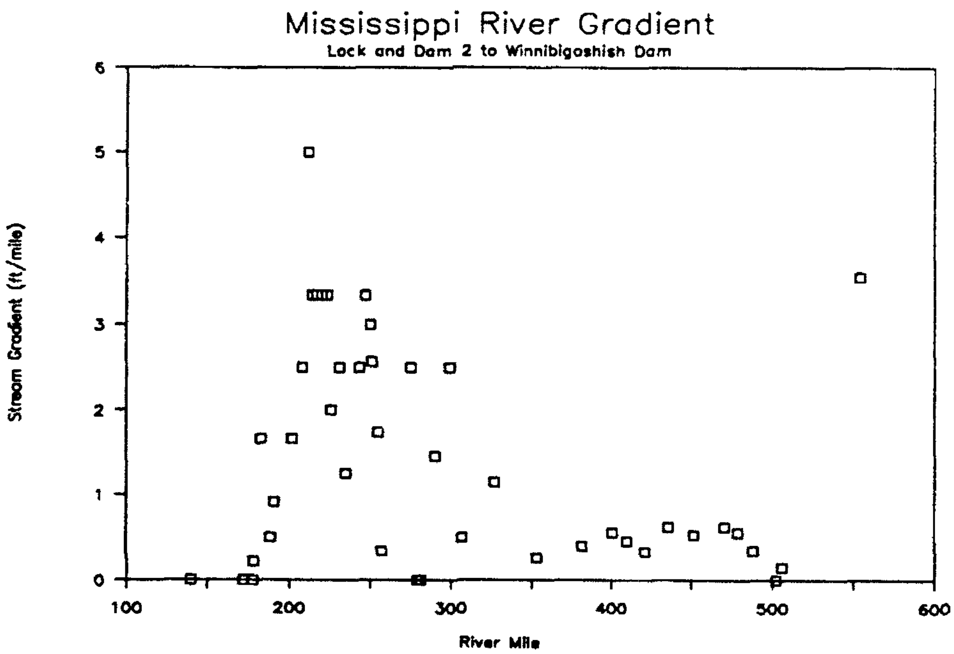


Figure E-2. Mississippi River gradient Lock and Dam 2 to Winnibigoshish Dam.

an island-braided channel and a sandy bed that is armored in places with stone cobbles and gravel. At the Falls of St. Anthony, the river descends into a narrow gorge. Through the gorge, the channel is confined by rock outcroppings and the substrate is sand and gravel. The valley and the river channel widen downstream of St. Paul, with Minnesota River sediments providing a fine-grained substrate.

Human Use of the River

1.7 The river changes from a pristine near-wilderness stream in the headwaters to a heavily industrialized river in the Minneapolis-St. Paul metropolitan area. Appendix C describes water appropriations and return flows. Organic pollutant loading from point sources is not sufficient to degrade water quality. Plant nutrient loading from nonpoint sources is significant, but nutrient concentrations in the river have not resulted in excessive plant and algal growth upstream of the metropolitan area. The river is used for assimilation of thermal waste from a number of power plants. With the exception of the Monticello Nuclear Generating Plant, the thermal mixing zones are small. None of the thermal discharges have significantly changed the composition or abundance of aquatic life in the river. Contaminant loading has caused unacceptable levels of polychlorinated biphenyls (PCB's) in fish downstream of Little Falls, Minnesota.

1.8 Nearer the project, the Minnesota Chippewa members use the river for commercial and subsistence hunting, fishing and gathering purposes. Recreational use of the river includes fishing, hunting, boating, water-skiing, and swimming. The river supports a popular sport fishery for walleye, muskellunge, and northern pike in the upstream reaches, and smallmouth bass, crappie, and channel catfish are caught in the downstream reaches. The fishery in the metropolitan reach of the river, long suppressed by poor water quality, is improving the smallmouth bass, crappie, walleye, sauger, channel catfish, and northern pike increasing in abundance. Anglers fish from the bank, by wading, and from shallow-draft small boats. The river is shallow throughout most of its length, limiting larger boats, water-skiing, and most swimming to the impounded areas upstream of dams. Canoeing is popular on the river because of the scenic, undeveloped character of most reaches, and the low degree of difficulty for canoeists. Fall hunting for waterfowl and white-tailed deer is also popular along the river.

Hydrology

1.9 The Mississippi River upstream of the Minneapolis and St. Paul metropolitan area (above the Anoka gage) drains approximately 19,100 square miles (table E-1). The northern half of the drainage is forested, and the southern half is primarily in agricultural use.

1.10 Average annual runoff of approximately 5.7 inches per year occurs in the 19,100-square-mile Mississippi River drainage above the Twin Cities. At St. Paul, with the addition of the Minnesota River drainage, the total drainage area is 36,800 square miles and the average annual runoff is about 4.1 inches.

1.11 Snowmelt accompanied by spring rains normally produces annual peak flows in April and May. The considerable storage afforded by the many lakes and wetland areas in the basin attenuates runoff events. The headwaters lakes are operated to provide flood protection, but the effective flood protection extends downstream only to about the town of Aitkin.

1.12 Summer precipitation in the basin can produce substantial increases in river discharge from thunderstorms associated with cold fronts. Late summer precipitation and river discharge are usually low, approximately equal to winter low flow. Fall rains normally fill the headwaters lakes and increase river discharge. Releases from the headwaters lakes over the course of the winter to attain target drawdown elevations prior to spring runoff add to the normally low winter discharge in the river.

1.13 The large number of lakes and extensive wetlands in the basin provide storage that attenuates flood peak discharges and that normally sustains low flows. There is considerable groundwater discharge to the Mississippi River from aquifers in glacial drift and outwash deposits, which also helps to sustain low flows.

River Regulation

1.14 Downstream of Winnibigoshish Dam, there are 11 main stem dams in the study reach: Pokegama and Grand Rapids Dams at Grand Rapids, Little Falls Dam, Blanchard Dam near Royalton, Sartell Dam, St. Cloud Dam, Coon Rapids Dam, Upper and Lower St. Anthony Falls Dams in Minneapolis, Lock and Dam 1 in St. Paul, and Lock and Dam 2 at Hastings, all in Minnesota. All the dams, except for Winnibigoshish and Coon Rapids Dams, have hydropower turbines and are generally operated in a run-of-river mode without significant fluctuations in releases for peaking power production. Operation of all the dams is directed toward maintaining pool elevation in their respective reservoirs. None of the main stem dams have significant storage capacity.

1.15 The Corps-operated dams from St. Anthony Falls through Lock and Dam 2 are navigation dams which are operated primarily to maintain a minimum pool elevation for the 9-foot navigation channel.

1.16 The routine low flow rate of release from the six Corps-operated headwaters lakes to the Mississippi River totals 270 cfs. The low flow releases are initiated when the respective lake levels fall to certain trigger elevations. The low flow release is distributed with 100 cfs from Lake Winnibigoshish, 100 cfs from Leech Lake, the 200 cfs from Leech and Winnibigoshish Lakes passed on through Pokegama Dam at Grand Rapids, 20 cfs from Sandy Lake, 30 cfs from Pine River Dam, and 20 cfs from Gull Lake. This routine low flow release is often attained during the latter half of the summer during normal conditions. The routine low flow release is continued during drought conditions, under the existing operating plan, until lake water levels become unacceptably low. Once lake stages fall below another, lower set of trigger elevations, releases from the headwaters lakes are to be reduced by half.

Low Flow Characteristics

1.17 The most recent analysis of Mississippi River low flows was performed by the U.S. Geological Survey (Arntson and Lorenz 1987). Low flow frequency characteristics from the Geological Survey report are shown in table E-2. The discharge figures reflect the entire period of record for each gage, not including the 1988 low flows. When these discharge, figures are recomputed by the USGS, including the 1988 data, it is expected that most discharge figures shown on the table will decrease. The 7-day duration low flow that can be expected on average once every 10 years (7Q10) at Grand Rapids is 91.9 cfs. The 7Q10 estimated for Anoka is 1180.0 cfs, over 12 times greater. The low

Table E-2. Low flow frequency characteristics of the Upper Mississippi River.

LOW FLOW FREQUENCY CHARACTERISTICS DATA TAKEN FROM USGS WATER RESOURCES INVESTIGATIONS REPORT 86–4353						
	100 YR.	50 YR.	20 YR.	10 YR.	5 YR.	2 YR.
WINNIBIGOSHISH	MISSISSIPPI	RIVER				
1 DAY	31.2	37.1	46.9	56.6	69.3	94.5
7 DAY	36.0	41.6	50.9	60.1	72.2	97.4
30 DAY	44.7	50.0	59.0	68.0	80.4	109.0
GRAND RAPIDS	MISSISSIPPI	RIVER				
1 DAY	0.0	0.0	31.9	64.3	117.0	267.0
7 DAY	20.8	31.9	57.4	91.9	153.0	342.0
30 DAY	40.6	59.6	102.0	158.0	254.0	545.0
LIBBY (BELOW SANDY RIVER)	MISSISSIPPI	RIVER				
1 DAY	68.4	91.4	138.0	196.0	293.0	585.0
7 DAY	99.2	128.0	185.0	253.0	362.0	679.0
30 DAY	128.0	163.0	233.0	315.0	445.0	822.0
AITKIN	MISSISSIPPI	RIVER				
1 DAY	140.0	183.0	266.0	362.0	514.0	923.0
7 DAY	177.0	224.0	314.0	416.0	573.0	990.0
30 DAY	212.0	271.0	381.0	505.0	693.0	1180.0
ROYALTON	MISSISSIPPI	RIVER				
1 DAY	216.0	274.0	384.0	508.0	699.0	1200.0
7 DAY	309.0	389.0	536.0	700.0	944.0	1560.0
30 DAY	366.0	455.0	619.0	802.0	1070.0	1770.0
ELK RIVER	MISSISSIPPI	RIVER				
1 DAY	357.0	432.0	571.0	725.0	961.0	1600.0
7 DAY	415.0	509.0	682.0	874.0	1160.0	1920.0
30 DAY	470.0	574.0	765.0	977.0	1300.0	2130.0
ANOKA	MISSISSIPPI	RIVER				
1 DAY	506.0	608.0	791.0	990.0	1280.0	2030.0
7 DAY	552.0	683.0	923.0	1180.0	1570.0	2510.0
30 DAY	601.0	752.0	1030.0	1340.0	1790.0	2910.0
ST. PAUL	MISSISSIPPI	RIVER				
1 DAY	637.0	757.0	975.0	1210.0	1560.0	2460.0
7 DAY	768.0	907.0	1160.0	1430.0	1820.0	2810.0
30 DAY	884.0	1040.0	1310.0	1610.0	2040.0	3120.0
LEECH LAKE RIVER AT FEDERAL DAM						
1 DAY	29.8	35.6	45.3	54.6	66.2	87.1
7 DAY	38.5	43.7	52.0	60.0	70.3	91.1
30 DAY	46.8	51.3	58.8	66.1	76.1	98.3
SANDY RIVER AT SANDY LAKE DAM						
1 DAY	0.0	0.0	0.0	0.0	0.0	4.9
7 DAY	0.0	0.0	0.0	2.9	5.1	11.4
30 DAY	1.9	2.4	3.5	4.9	7.3	15.9
PINE RIVER AT CROSS LAKE DAM						
1 DAY	2.9	4.4	7.7	12.0	19.3	39.5
7 DAY	6.5	8.2	11.7	15.7	22.1	40.6
30 DAY	8.7	11.2	16.0	21.6	30.4	54.5
GULL RIVER AT GULL LAKE DAM						
1 DAY	2.2	3.0	4.5	6.4	9.1	15.8
7 DAY	2.9	3.9	5.7	7.8	10.7	17.3
30 DAY	4.0	4.9	6.6	8.4	11.3	19.3

NOTE: These figures were computed without the 1988 low flows. It is expected that if the 1988 low flows were used, then lower discharges would be computed for all of these locations and recurrence intervals.

flow characteristics of the river over the period of record shown in table E-2 do not effectively represent low flow characteristics of the river under the present operating plan for the headwaters lakes, because the present operating plan for the headwaters lakes has not been in effect over the entire period of record. The low flow data in table E-2 does, however, give a good approximation of present-day low flow characteristics of the river.

1.18 Operation of the Mississippi River headwaters lakes influences river discharge mostly in the upper reaches of the river during periods of normal river discharge. During periods of extremely low river discharge, releases from the headwaters lakes constitute a significant percentage of river discharge for a much greater distance downstream. During the 1988 drought period, releases from the headwaters lakes comprised approximately 25 percent of river discharge at Anoka, with consideration of travel losses in route.

Approach to Assessing Instream Flow Needs

2.0 Instream flow to sustain riverine life and to support recreational uses can be considered nonconsumptive water demands that can be quantified according to rate of river discharge needed during various times of the year. Quantifying instream flow needs is problematic, because of the complexity of aquatic life, the indistinct relationship between habitat availability and populations, the variety of factors influencing the strength of fish populations, the difficulty of predicting stream hydraulic conditions, non-quantitative management goals, and especially in this case, because of the long reach of river (421 miles) under consideration.

2.1 Observation and measurement of habitat availability and biotic response to conditions at various levels of river discharge is a direct and most valuable approach to assessing instream flow needs. Because of the infrequent low flow conditions on the Mississippi River, instream flow needs assessment by direct observation and measurement has not occurred. The Minnesota Department of Natural Resources (MDNR) fisheries managers did, however, make qualitative observations of habitat conditions, conducted routine fishery surveys, and monitored angler catch on the Mississippi River during the summer of 1988.

<u>Identification of Management Goals for the River and Observations of 1988 Low Flow Conditions</u>

2.2 Minnesota Department of Natural Resources fisheries biologists with management responsibilities for the different parts of the river were interviewed in March 1989. The discussion focused on their direct observations of habitat conditions during the 1988 drought period and their management goals for the sport fishery. Comments provided by the fisheries managers follow.

2.3 Winnibigoshish Dam to Pokegama Dam - This uppermost part of the study reach has a fairly low gradient and a sandy bed. Management goals for the sport fishery are to maintain resident populations of walleye and northern pike. The fish in this reach of river are quite mobile and seem to be attracted upstream by higher flows. Higher flows attract fish into Little Winnibigoshish Lake. Spawning runs of walleye and northern pike congregate below Winnibigoshish Dam and Mud Lake Dam on the Leech Lake River. There is concern about exchange of water between the river and White Oak Lake during low flow periods and about winter dissolved oxygen in the lake. The routine low flow releases of 100 cfs from Leech Lake and 100 cfs from

Winnibigoshish Lake appear to adequate for maintaining aquatic life, recreational use, and water quality in this part of the river during low flow periods.

2.4 Pokegama Dam (Grand Rapids) to Aitkin County Line- The lake fishery above Bladin Paper Company dam in Grand Rapids has muskies, walleyes, and northerns. The tailwater of Pokegama Dam is a popular fishing location. No water quality or habitat problems associated with low flow periods have been noted in the reservoir. Downstream of the Bladin dam, the management goals are to maintain populations of smallmouth bass, walleye, northern pike, and muskellunge. Releases from Blandin dam in Grand Rapids have artificially reduced river discharge during low flow periods, causing some stranding downstream, and possibly aggravating any water quality problems associated with effluents from the Grand Rapids area. No water quality problems were noted in this reach during the 1988 low flow period, however.

2.5 Aitkin County Reach - This reach of Mississippi River has a relatively deep, meandering channel with low gradient. Much of the habitat is pool with considerable volume and depth of habitat available, even during low river discharge. River oxbow lakes and embayments become isolated from the river during low flow periods, resulting in stranding and important slackwater habitat denied to the fishery. Management is directed toward maintaining populations of smallmouth bass, walleye, northern pike, and muskellunge in this reach of river. A 1988 fish survey revealed that low spring flows limited northern pike spawning, as evidenced by low numbers of young-of-year and adulst pike reabsorbing eggs. The 1988 extreme low flow apparently did not cause significant fishery or water quality problems in the Aitkin County reach of river. Angling opportunity was good, and tributary inlets were popular fishing spots. Low river stages hindered boat launching. However, wild rice production was decreased, with poor quality rice occurring or light heads of plants. Access for wild rice harvest was difficult.

2.6 Pine River - The value of the tailwater of the Pine River Dam as fish habitat declines considerably when the Corps reduces releases to the normal minimum of 30 cfs. The northern pike, walleye, and panfish that support the tailwater sport fishery during periods of higher river discharge apparently move downstream.

2.7 Gull River - The Gull River provides a spring tailwater fishery below Gull Lake Dam. As river discharge declines, fish move to the pooled area downstream of Highway 210.

2.8 Mississippi River from Aitkin County Line to Little Falls - This reach of river supports smallmouth bass, muskellunge, and northern pike. About 80 percent of the fish biomass is redhorse. Sport fishing pressure is usually low. The river has a mostly rock rubble substrate in the upper part of the reach, and widens out near Crow Wing State Park, where there are good numbers of walleye and largemouth bass. From Brainerd to Little Falls, the river is sandy, with islands and few meanders. Management is directed toward smallmouth bass, walleye, and muskellunge. Muskellunge eggs are stripped from fish captured in the river, and young muskellunge are stocked. A small channel catfish population is present and is increasing. Smallmouth bass appear to be positively affected by the recent low flow conditions, with good recruitment occurring in 1987 and 1988. No major fishery problems

were observed associated with the 1988 summer low flow period. Northern pike reproduction was poor because the low spring flows limited area of spawning habitat for pike. Exodus of fish from tributary streams to the Mississippi River was observed. Sport fishing opportunity was good, and exploitation was heavy during the summer low flow period. Boat access to the river was limited at landings because of the low river stage. Canoeing on this reach of the river is popular, and there are several new canoe liveries. Canoeing was difficult because of sandbars and low river stages downstream of Crow Wing State Park.

2.9 Little Falls to Twin Cities Metropolitan Area - The reach of river between St. Cloud and Anoka supports a very popular fishery for smallmouth bass. Management is directed toward smallmouth bass and walleye. Channel catfish and muskellunge populations are increasing. Sport fishing opportunity was good during the 1988 low flow period, and exploitation was heavy. Fish consumption advisories because of contaminants in fish downstream of Little Falls will change the fishery toward catch-and-release. No particular drought-related problems with the fishery were noted.

2.10 Metropolitan Area to Lock and Dam 2 - Relatively little sport fishing takes place in this reach of river, and fish consumption advisories are in effect because of contaminant problems. The primary concern about effects of low flow on the fishery was with water quality, not availability of habitat in the pooled portion of the river.

Instream Flow Incremental Methodology

2.11 Another approach to assessing instream flow needs is to estimate habitat availability at different levels of river discharge. A variety of methods have been applied to this approach. The Instream Flow Incremental Methodology (IFIM) (Bovee, 1982) and its variations have been widely used. This method combines results of numerical hydraulic modeling with models of habitat suitability for aquatic life. The method requires measurement or simulation of hydraulic conditions in the river and application of habitat suitability models for aquatic life forms.

2.12 The Corps of Engineers provided planning assistance to the MDNR under Section 22 of the Water Resources Development Act of 1974, to help the MDNR develop a program of instream flow needs assessment for the State. The work, conducted in 1977 through 1984, consisted of hydraulic surveys of the Mississippi River between St. Cloud and Elk River, development of numerical hydraulic models, and sampling to develop habitat suitability models for selected fish species. Because of the availability of the hydraulic survey data, and availability of more recently-developed habitat suitability models, the decision was made to conduct an IFIM analysis. Time and funding constraints prevented the collection of new hydraulic survey data or the survey of other reaches of the Mississippi River.

Application of Instream Flow Incremental Methodology for the St. Cloud to Elk River Reach of the Mississippi River

3.0 During the winter of 1988, the Corps of Engineers requested that the MDNR assist in application of IFIM methodology application is adapted from Domingue (1988).

3.1 In order to generate simulations of hydraulic conditions in the river, a set of hydraulic survey data developed during the Section 22 effort was provided to the MDNR. These data were used to run physical habitat simulation models known as PHABSIM developed by the U.S. Fish and Wildlife Services (USFWS), National Ecology Center, Aquatic Systems Branch (NEC) (formerly, the USFWS Instream Flow Group).

3.2 The hydraulic survey data were collected by the U.S. Geological Survey (USGS) in 1980. The surveys consisted of channel configuration surveys, substrate type observations, and velocity measurements collected from transects across the river within seven reaches from below St. Cloud to Elk River (figures E-3 through E-8).

3.3 Numerical hydraulic models developed for the IFIM methodology were applied to simulate hydraulic conditions within the surveyed river reaches by the USGS. These models were provided to the MDNR along with the hydraulic survey data.

3.4 Results of hydraulic simulations were integrated with models of fish habitat suitability to generate families of habitat availability vs. discharge curves.

<u>Numerical Hydraulic Modeling</u>

3.5 Velocity measurements for hydraulic model calibration were made at only two, fairly similar, levels of river discharge (2,500 cfs and 4,000 cfs). This presented several problems in simulation of hydraulic conditions at other levels of river discharge and in model calibration.

3.6 It is generally accepted that PHABSIM models should not be used to simulate conditions at flow greater than 2.5 times the highest calibration discharge. This limits extrapolation to discharge of around 10,000 cfs.

3.7 Prediction of hydraulic conditions in most rivers with PHABSIM models is better at discharges less than the calibration discharge than above it. The purpose of this analysis is to assess low flow conditions - not high flow conditions. However, simulation of hydraulic conditions at extremely low levels of river discharge is complicated by charges in channel morphology that occur during extend periods of low flow, as the stream channel becomes incised into the bed of the normally large stream.

3.8 In 1980, the models originally developed were run using standard PHABSIM technique of the time, which relied on stage:discharge technique of simulation, which are prone to error. In the current assessment, stage was

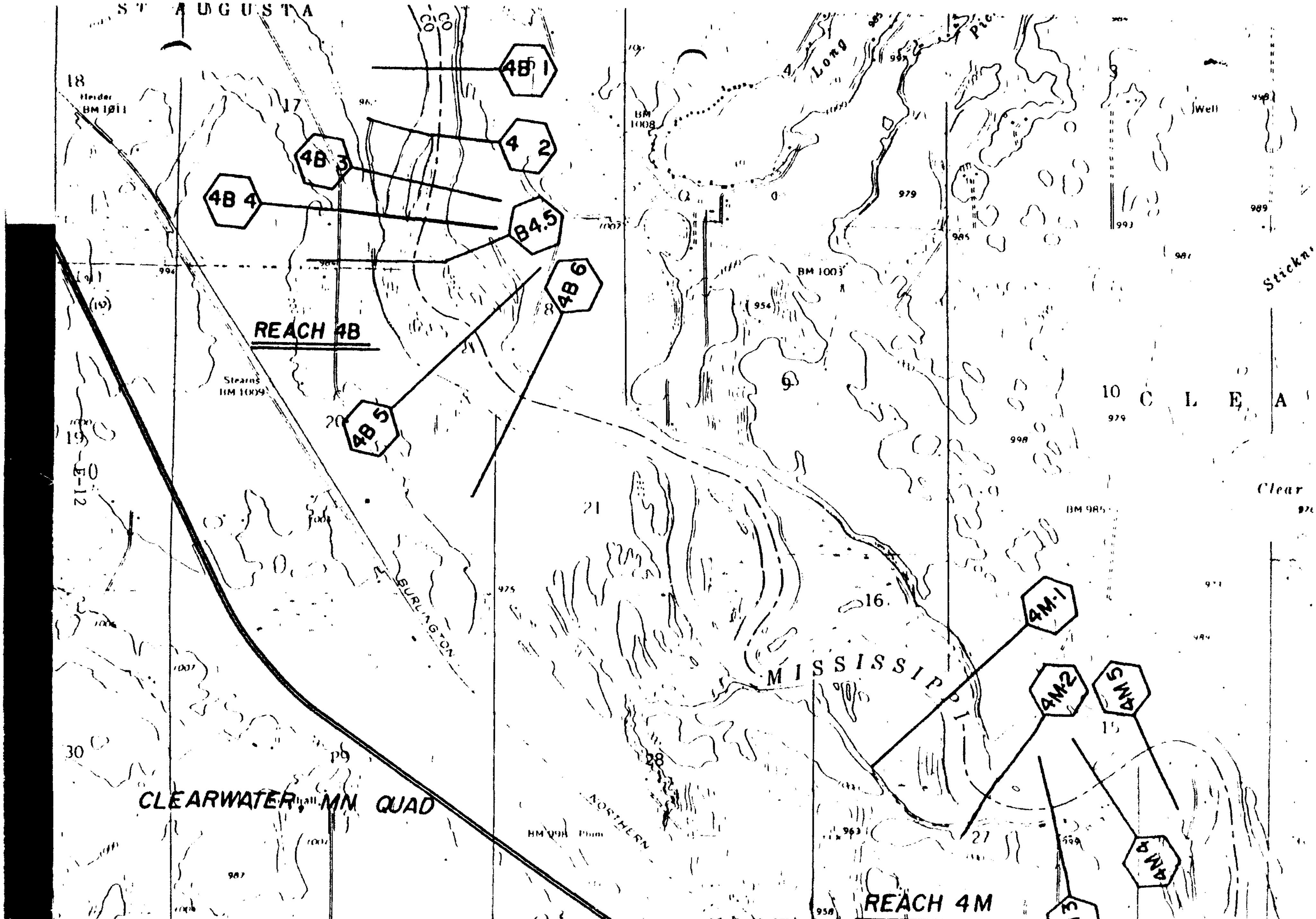


Figure E-3. Location of hydraulic survey transects, reaches 4B and 4M, Mississippi River near Clear Lake, Minnesota

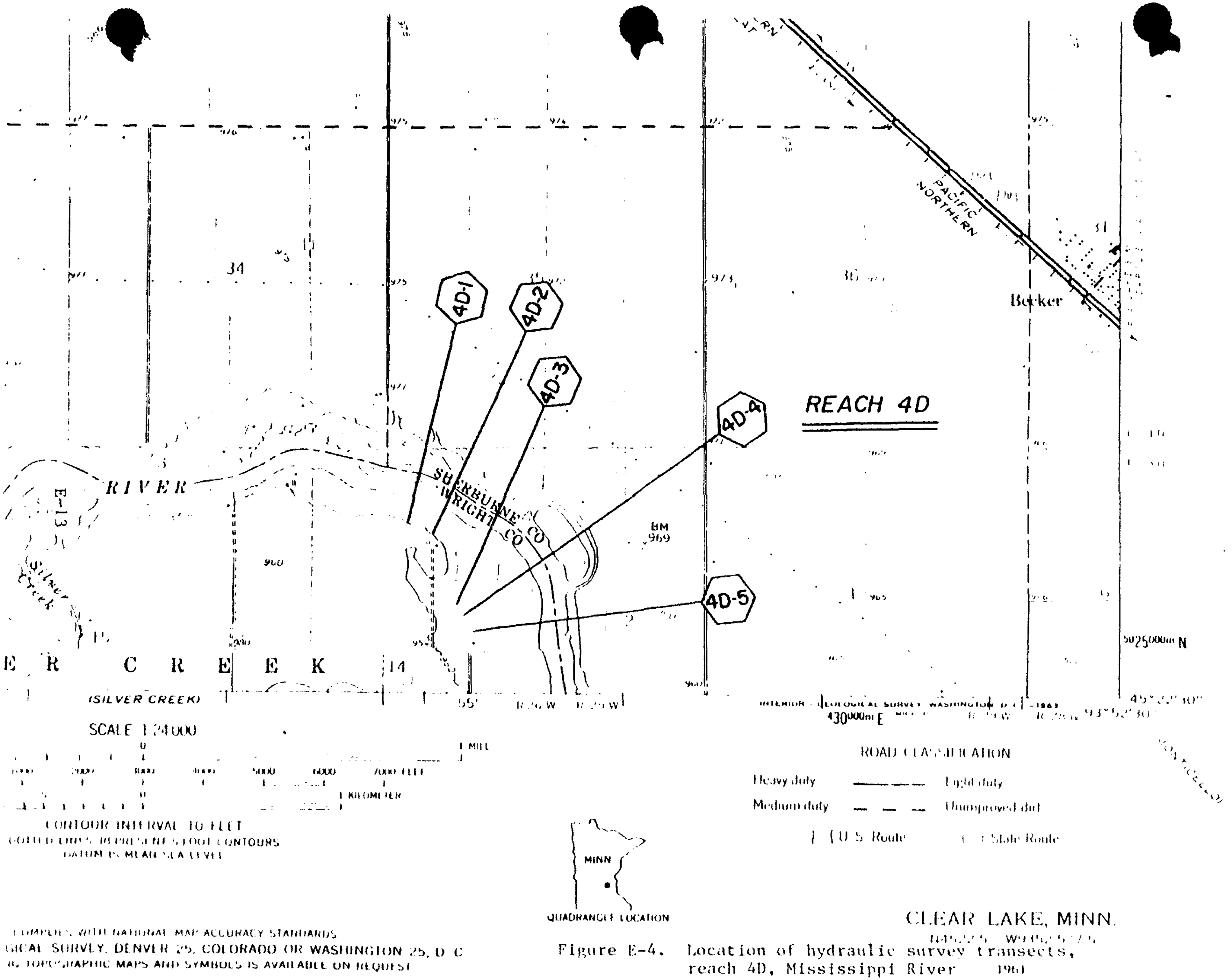


Figure E-4. Location of hydraulic survey transects, reach 4D, Mississippi River near Becker, Minnesota.

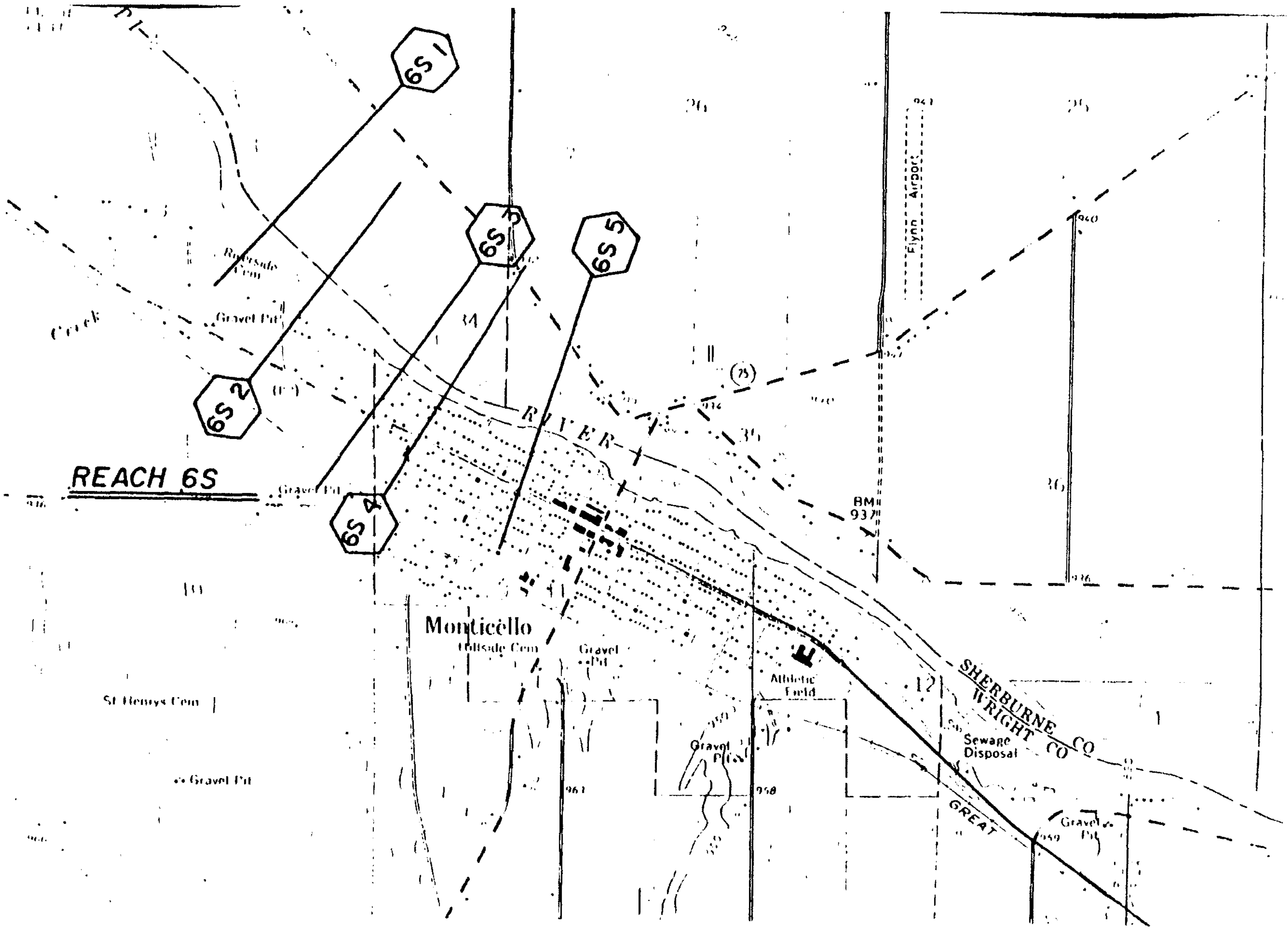


Figure E-5. Location of hydraulic survey transects, reach 6S Mississippi River near Monticello, Minnesota.

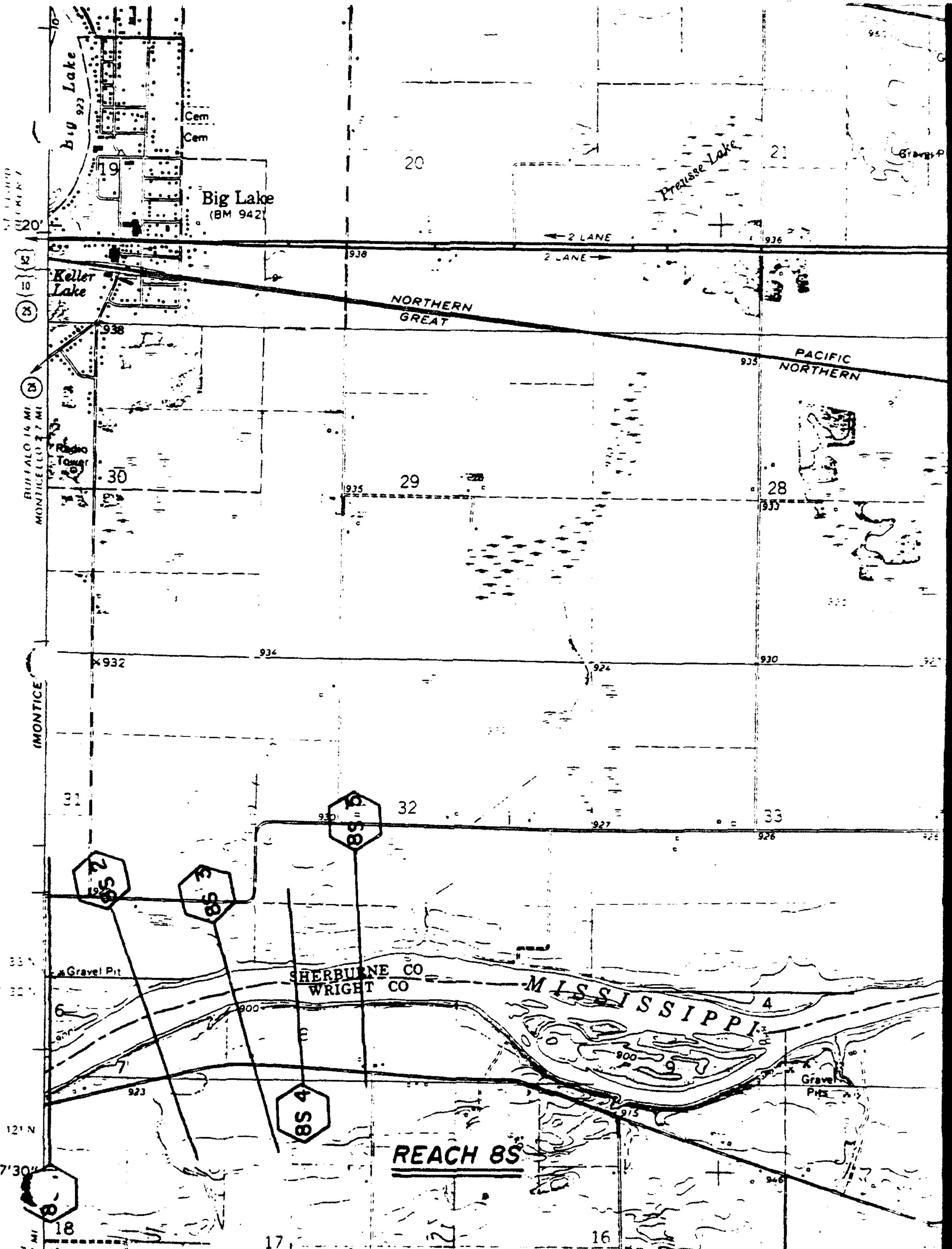


Figure E-6. Location of hydraulic survey transects, reach 8S, Mississippi River near Big Lake, Minnesota.

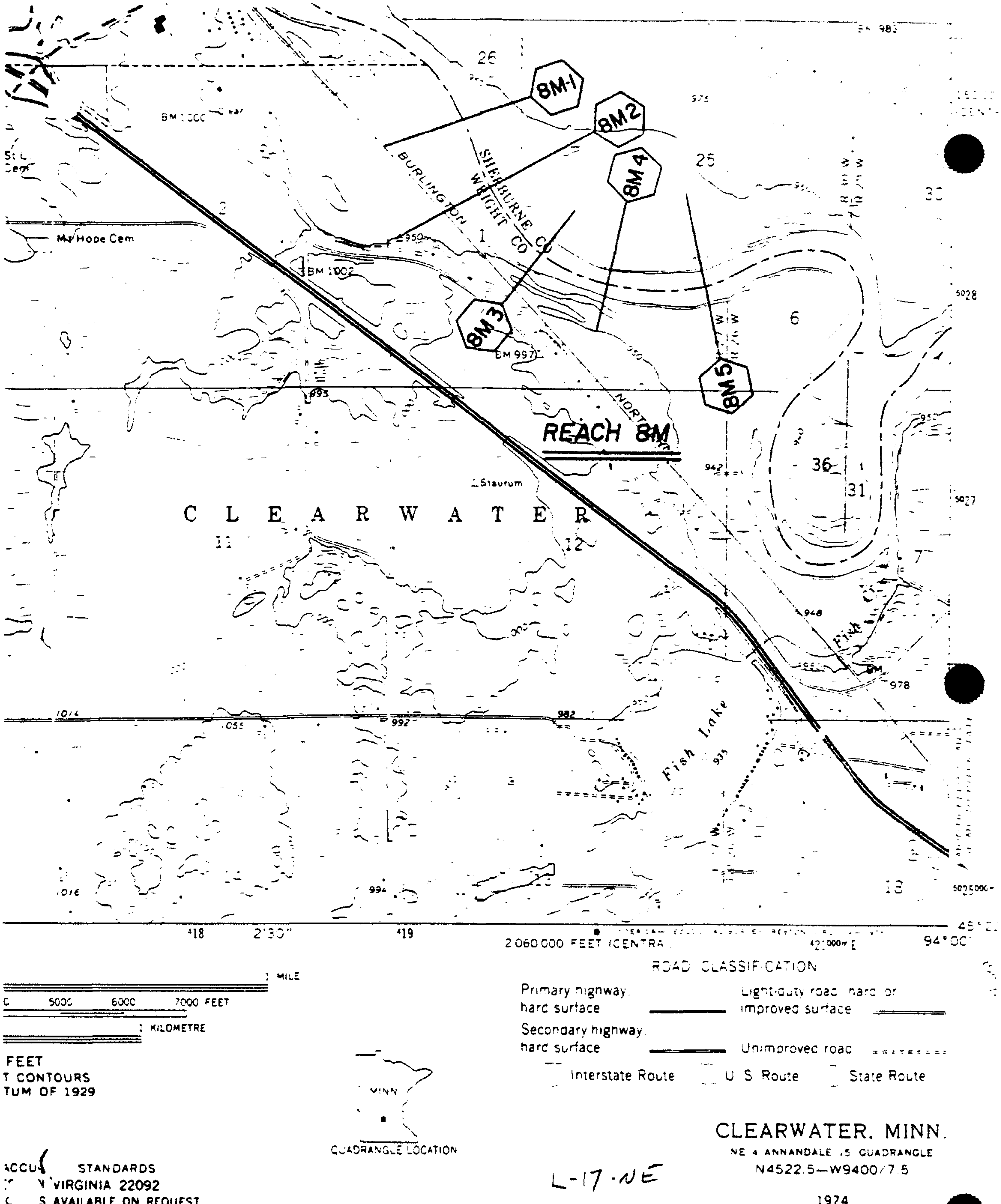


Figure E-7. Location of hydraulic survey transects, reach 8M, Mississippi River near Clear Lake, Minnesota.

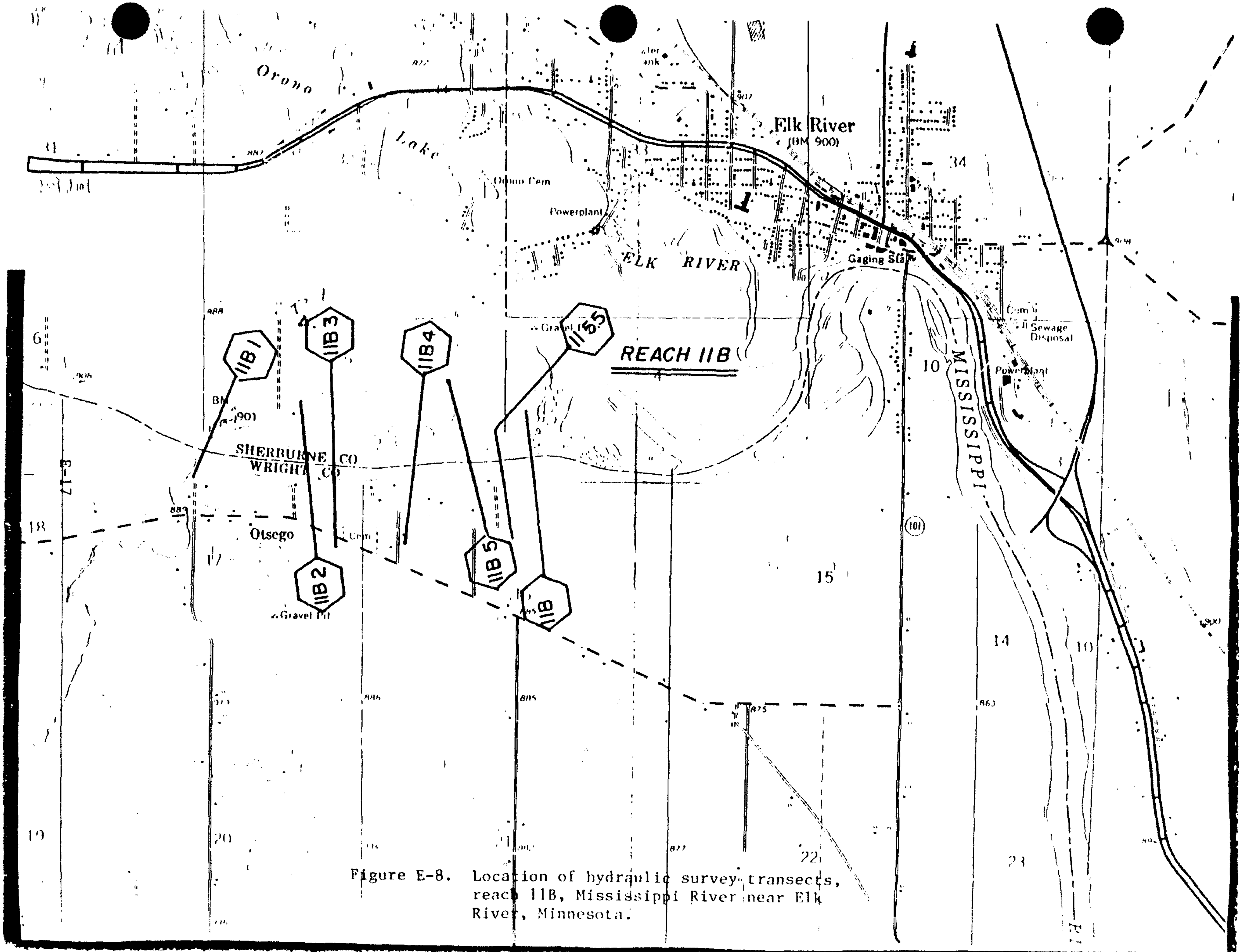


Figure E-8. Location of hydraulic survey transects, reach 11B, Mississippi River near Elk River, Minnesota.

simulated using the step-backwater technique, using a PHABSIM model called WSP. Stage simulations using WSP were found to be superior to stage: discharge-generated stage predictions on all but one of the modeled river reaches.

3.9 Each model was calibrated using WSP. The calibration process involves modifying bed roughness coefficients until the measured water surface elevations can be accurately simulated. The model would first be calibrated using one discharge and then modified to simulate the second. In several instances, it was very difficult to simulate the second discharge, and these models were termed "fair". Models which accurately water surface elevations at both discharges were considered "good". Table E-3 identifies the quality of the model.

Table E-3. Calibration of hydraulic models used in instream flow needs assessment for the Mississippi River.

Model/River Reach	Stream Morphology Within Reach	Model Calibration
4B	island brained	fair to poor
4D	island brained, deep	fair
4M	deep pool	fair
6S	straight run	good
8M	meander bend	fair to good
8S	straight run	good
11B	island brained	fair to good

3.10 The descriptions in table E-3 are based on the model fit between the two measured discharges. In general, models were considered good if fit within 0.05 foot of simulated river stage could be obtained for each transect. Models were calibration of WSP was between 0.05 and 0.1 foot are defined as fair. Where it was not possible to fit all transects within 0.1 foot of the measured water surface elevations at both discharges, the model was given a poor rating.

Wetted Perimeter Modeling

3.11 Shallow riffle areas are the most productive areas in rivers and are most sensitive to change at low levels of river discharge. Pool areas do not change as much in volume, depth, and extent as do riffle areas when river discharge declines.

3.12 Only relatively shallow, riffle area transects were chosen for the wetted perimeter analysis. Models were developed for the selected transects, and the stream width was generated for depths of 0.5, 1.0, and 1.5 feet. These depths are significant to recreational use and are a useful measure of physical habitat available for aquatic life. The model used to generate these curves is part of the PHABSIM family of models.

Recreation Conditions Modeling

3.13 River discharge greatly affects the suitability of stream conditions for recreation use. Wading, angling, and canoeing are popular activities on the Mississippi River in the study reach. the MDNR Division of Waters developed suitability models for wading/fishing and for family canoeing. These models were applied to estimate available area for these activities in the study reach at different levels of river discharge.

Fish Habitat Suitability Modeling

3.14 Habitat suitability modeling was performed for selected fish species, life stages, and guilds (groups of fishes with similar habitat requirements). The game fish habitat suitability models for northern pike and channel catfish were developed by the U.S. Fish and Wildlife Service National Ecology Research Center, Fort Collins, Colorado. These suitability models are based on literature reviews of fish habitat requirements. The walleye, smallmouth bass, shorthead redhorse, darter guild, and sand shiner habitat suitability models were developed by the MDNR Section of Fisheries. These and other MDNR fish habitat suitability models were developed from direct observations and location of capture data on habitat selected by the target species and life stages. A description of how the models were developed is contained in Aadland et al. (1989).

3.15 All habitat evaluations for this assessment were based solely on the habitat variables of depth, velocity, and substrate. Cover and temperature variables are likely important habitat constraints under low flows but were not used in this analysis because of a lack of data on these habitat conditions in the river.

3.16 Standard PHABSIM techniques were used. Velocity suitability data and simulations were based on mean water column velocities. The suitability of a cell is considered to be equal to the product of the suitabilities for depth, velocity, and substrate. The suitability of wet cells was then multiplied by the area of those cells. This product is termed Weighted Usable Area (WUA). The individual usable areas were summed in order to develop total weighted usable area of stream for each discharge simulated. The results are reported in terms of square feet of weighted usable area per 1,000 linear feet of stream. In this way, the results are expressed as area of suitable habitat per unit length of river.

Smallmouth Bass Habitat Suitability Models

3.17 Data on young of year smallmouth bass growth was provided to the MDNR for use in the Mississippi River IFIM modeling. This data is the result of research conducted by Simonson and Swenson and others for the Northern States Power Company (Swenson et al. 1981, Swenson et al. 1983, Simonson and Swenson 1989).

3.18 The data consisted of velocity dependent growth curves for smallmouth bass young-of-year and a set of habitat selection frequencies. The growth data was generated from flume studies, and data on habitat selection was obtained by direct observation of bass in the Mississippi River. Velocity measurements were made at the nose position of each fish. Curves were generated for "nose velocity" habitat suitability.

3.19 A set of habitat suitability curves was generated from the data and used in developing a habitat suitability model for smallmouth bass young-of-year growth. The growth data was used to develop both an "optimum" growth curve and an aggregate growth curve. The optimum growth curve is a binary type curve that assigns utility only to that portion of the growth curve which produced growth greater than 85 mg $g^{-1}d^{-1}$. The aggregate growth curve assigns velocity utilities relative to the growth rates observed throughout the range of observation. The in situ observation data was used to generate a suitability curve based on the relative frequency of observations.

3.20 Nose depth is defined as the location of the fish above the bottom of the channel. Swenson (personal communication with Domingue) reported that most young-of-year bass suspend within 0.1 foot of the bottom or, in the case of flume studies, within 0.1 foot of the sides of the flume. For modeling purposes, a nose depth of 0.1 foot above the bottom was assumed.

3.21 The hydraulic models employed use mean water column velocities to perform the hydraulic simulations. a general empirical relationship termed the 1/7th Power Law was used to predict nose velocities at 0.1 foot above the bottom fro the mean water column velocities generated by the hydraulic models.

Results of Instream Flow Needs Analyses

Wetted Perimeter

4.0 The depth vs. discharge results for the riffle area transects are perhaps the most consistent of the data generated (figures E-9 through e-11). Inflection points tend to lie between 1,600 cfs and 2,000 cfs. Width of wetted stream in the surveyed riffle areas at 500 cfs is approximately 0.7 foot of stream width at 1,600 cfs. Sufficient water depth remains at 500 cfs to allow movement of fish between pools through the riffle area. It appears that water depth may decline rapidly at river discharge levels below 500 cfs.

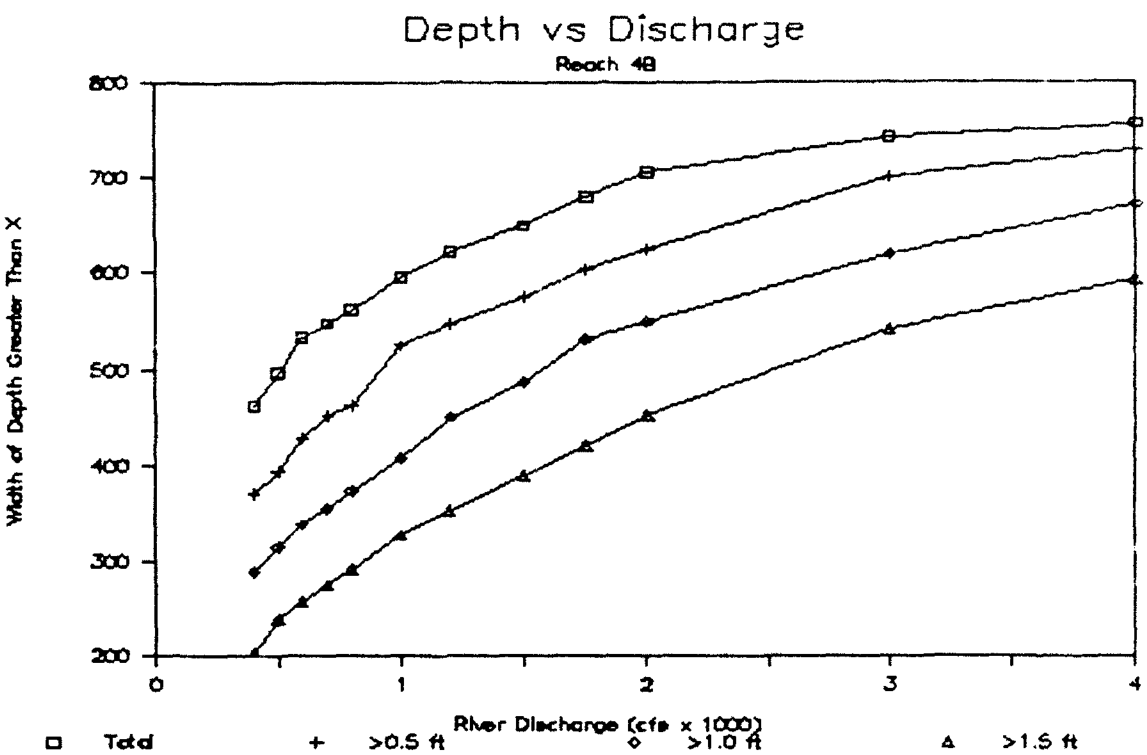
4.1 Low flow in the 1,600 to 2,000 cfs range may be desirable for the surveyed reach of the river. Maintaining water on the majority of the highly productive riffle substrate is important for production of food for aquatic life. During low flow periods, inflow from tributaries falls off to a minimum, and food available to aquatic life originates primarily from within the river. Food for aquatic life is available from periphyton, plankton, macrophytes, stored detritus, exodus of fish and other aquatic life from tributary streams, and lateral migration and drift of macroinvertebrates into the remaining channel. It is not known to what degree food for aquatic life is limiting during extended periods of low flow.

Habitat Available for Adult Fish

4.2 Results of IFIM modeling for adult shorthead redhorse, walleye, northern pike, and smallmouth bass are presented in figures E-12 through E-15.

4.3 In the unbraided runs (reaches 6S, 8M, and 8S) with good hydraulic model calibration, simulated habitat available for adult smallmouth bass held steady or increased slightly with decreasing discharge. Maximum area of suitable habitat for adult bass in reaches 6S and 8M is predicted to occur in the range of 500 to 600 cfs. Habitat available for shorthead redhorse is predicted to be near zero in these runs at 500 cfs because of insufficient velocity, and gradually increase in area with increasing discharge. Habitat available for adult walleye and northern pike is predicted to be minimal at all levels of river discharge.

4.4 In the island braided reach 11B, with good hydraulic model calibration, the simulated habitat available for adult bass remained fairly constant with river discharge throughout the entire range. Habitat available for shorthead redhorse is predicted to decline significantly below 1,500 cfs,



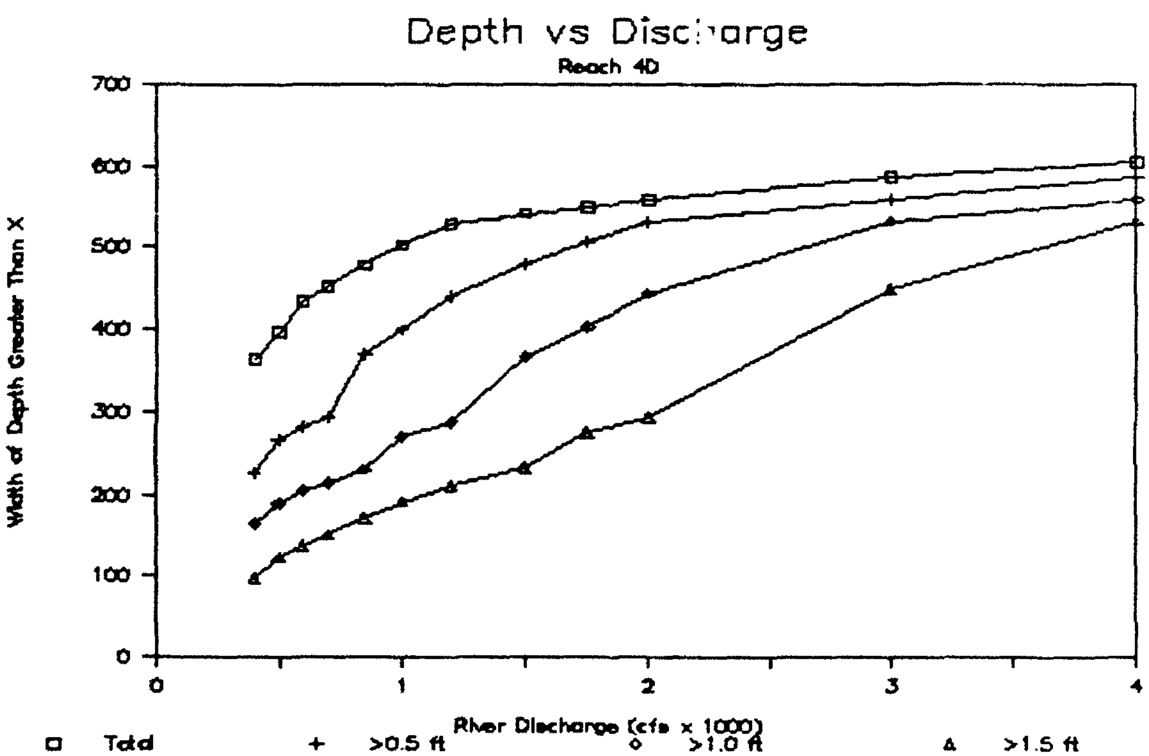
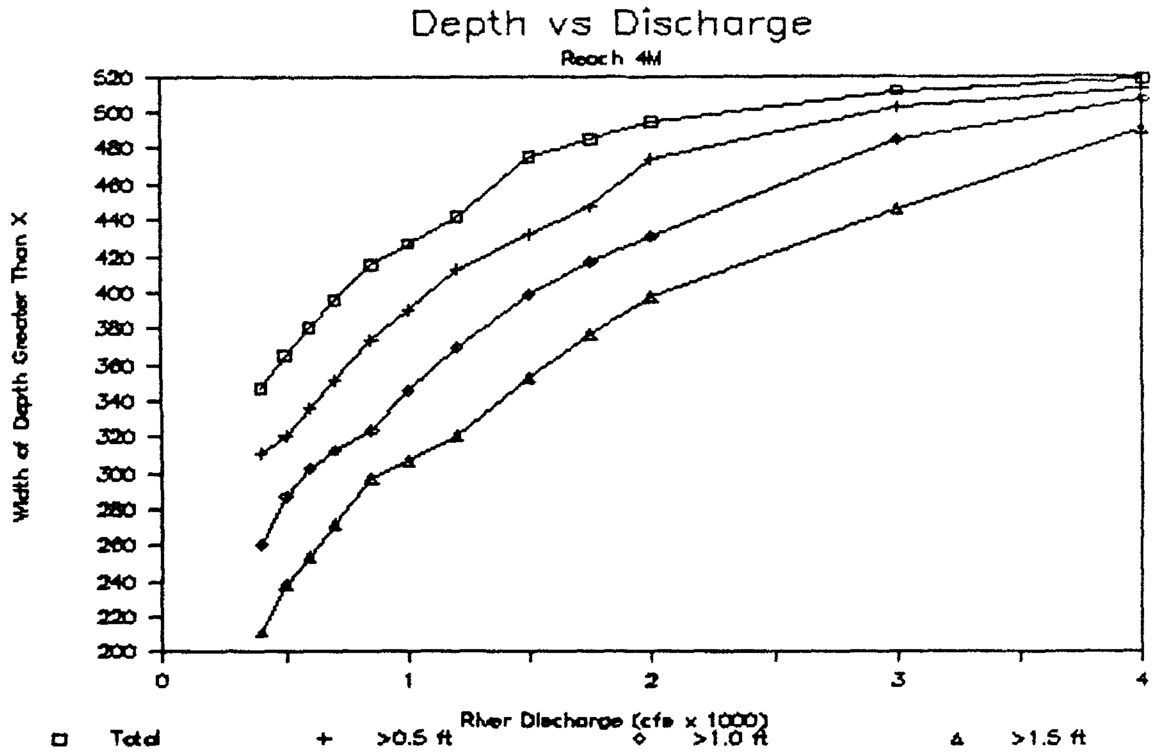


Figure E-9. Depth vs. river discharge, Mississippi River.



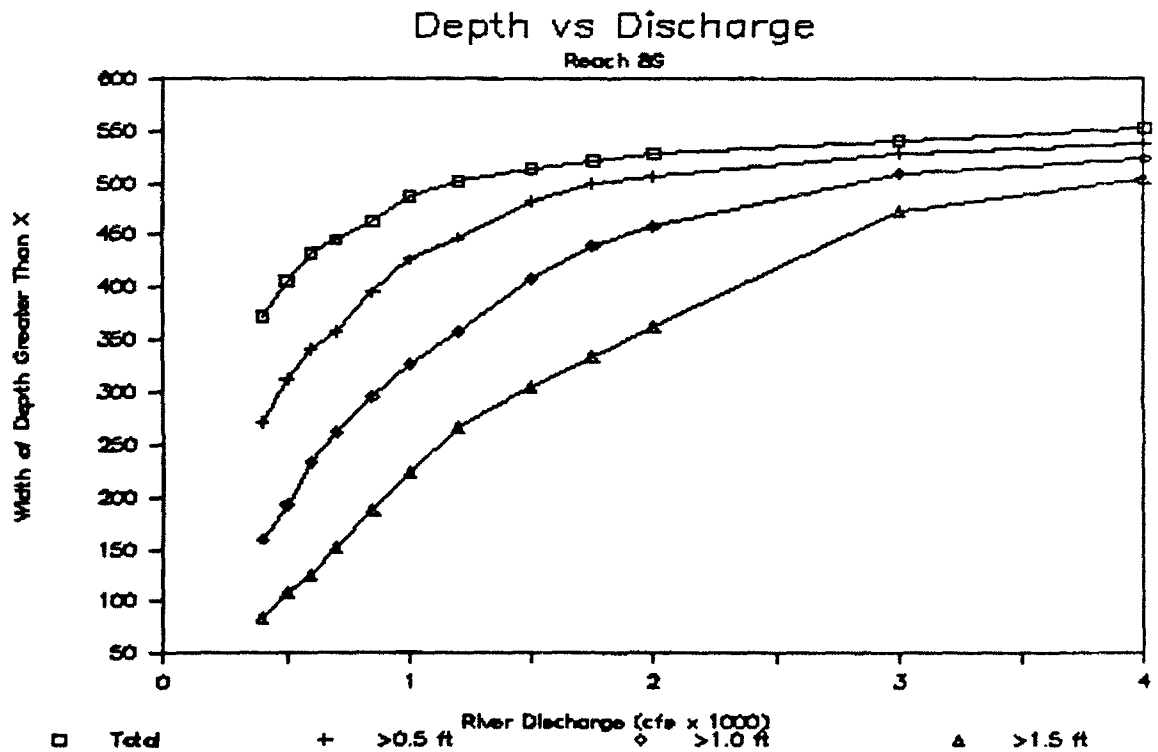


Figure E-10. Depth vs. river discharge, Mississippi River.

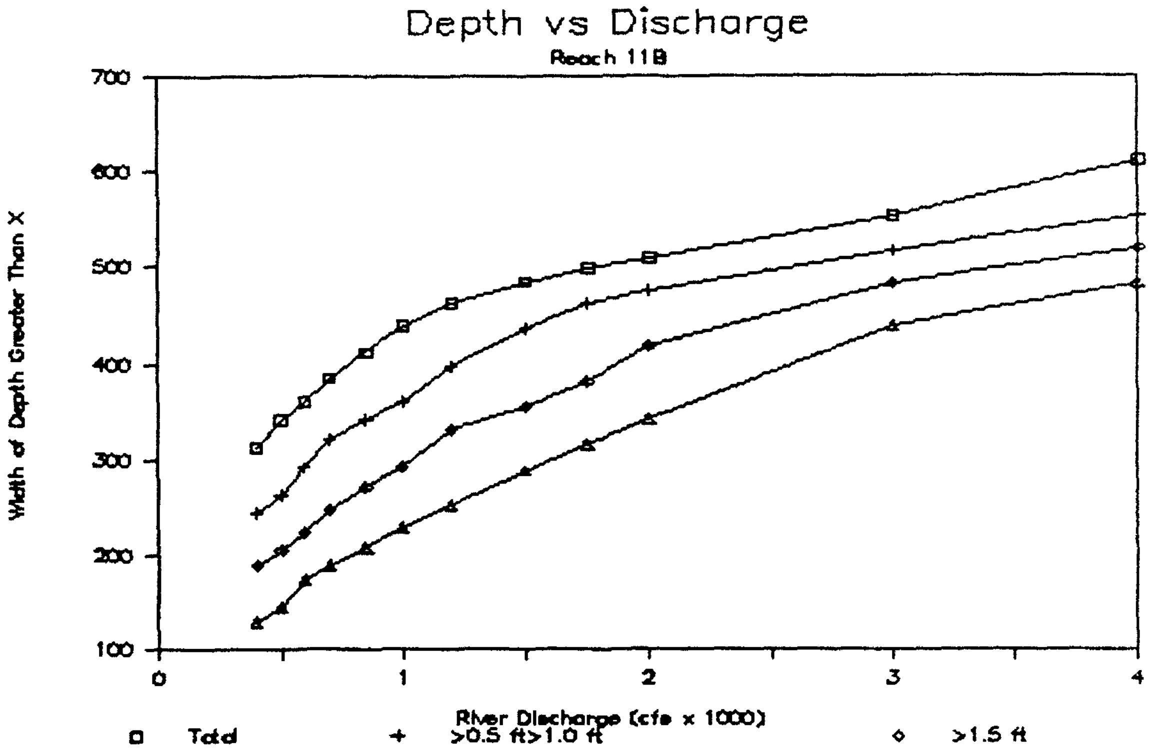
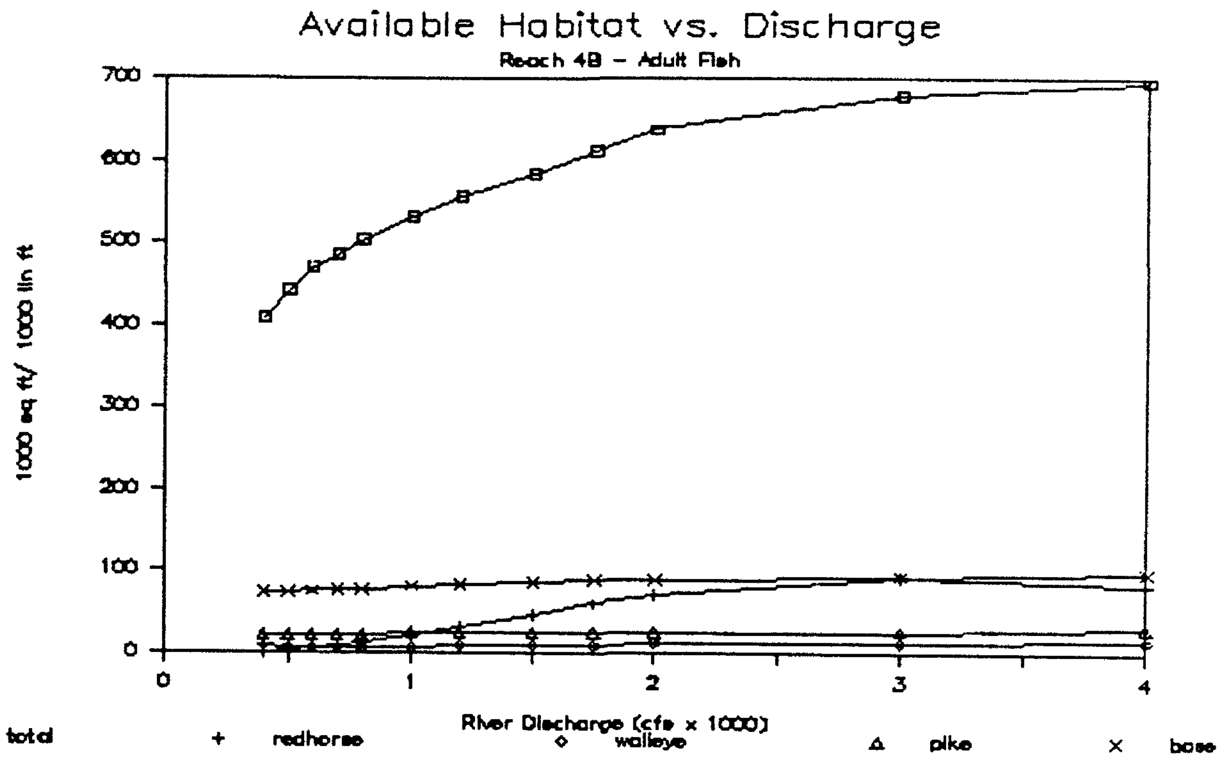


Figure E-11. Depth vs. river discharge, Mississippi River.



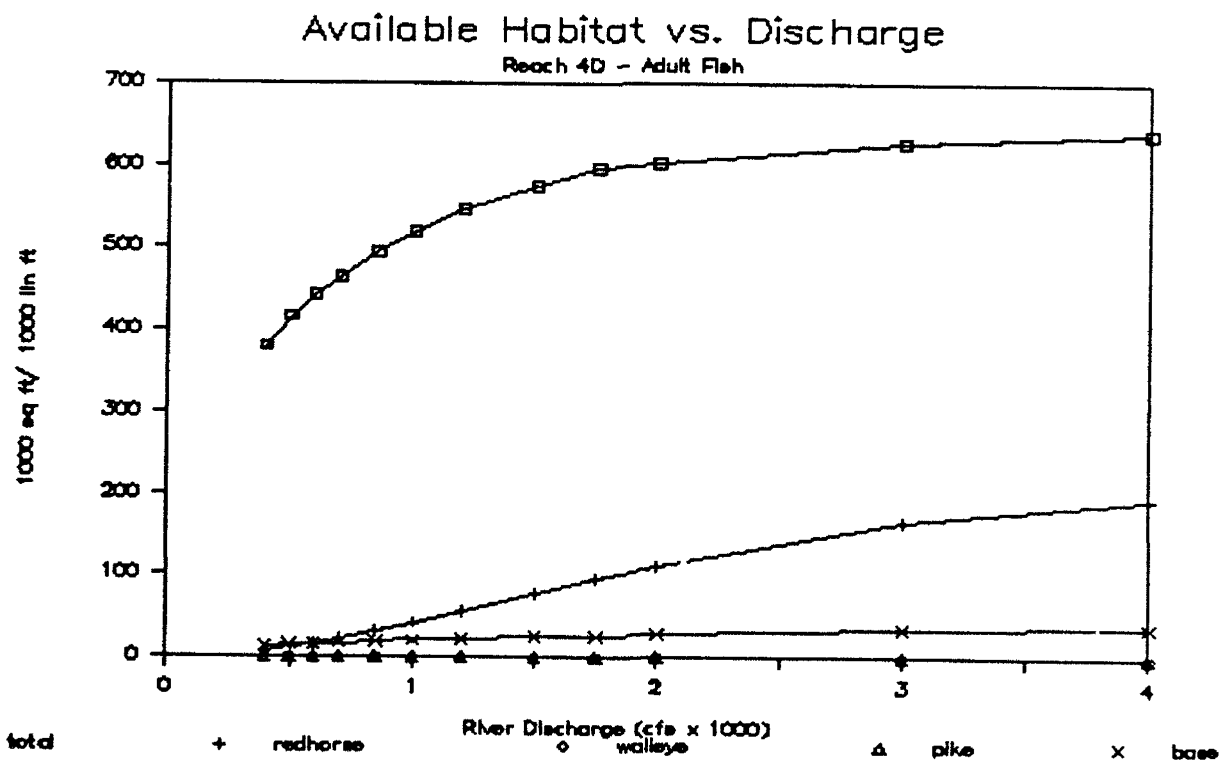
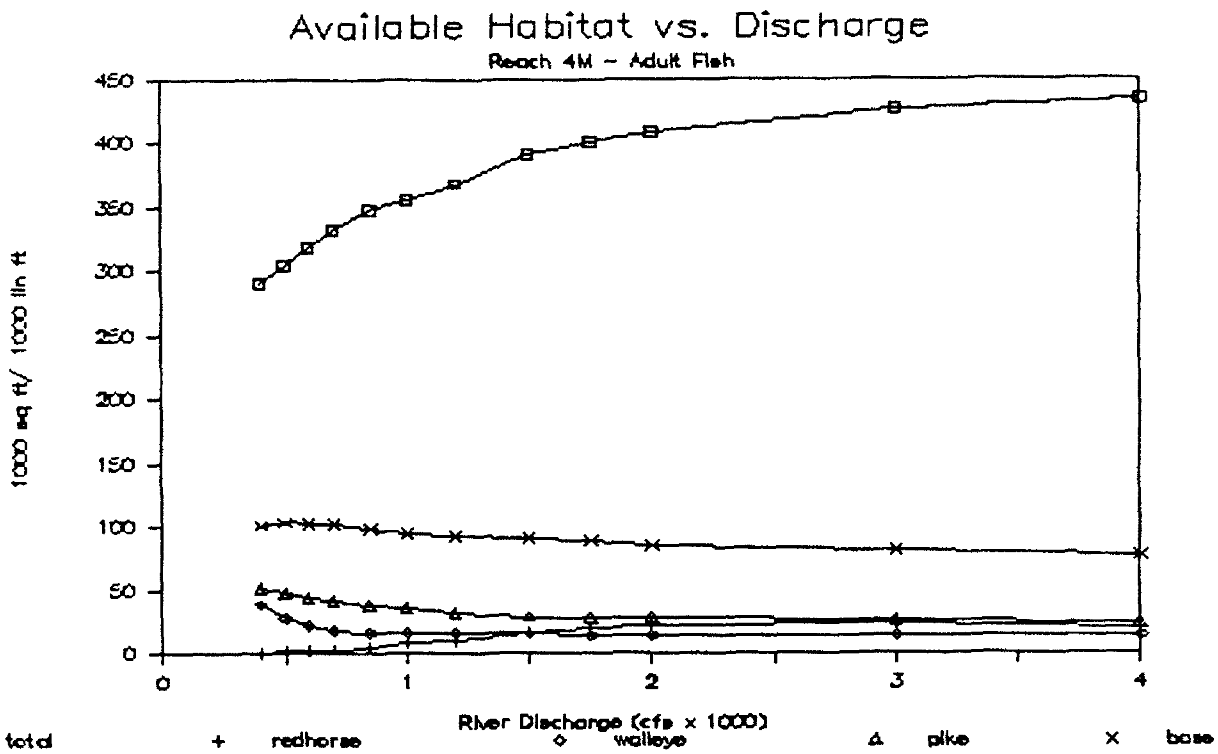


Figure E-12. Available habitat for adult fish vs. river discharge Mississippi River.



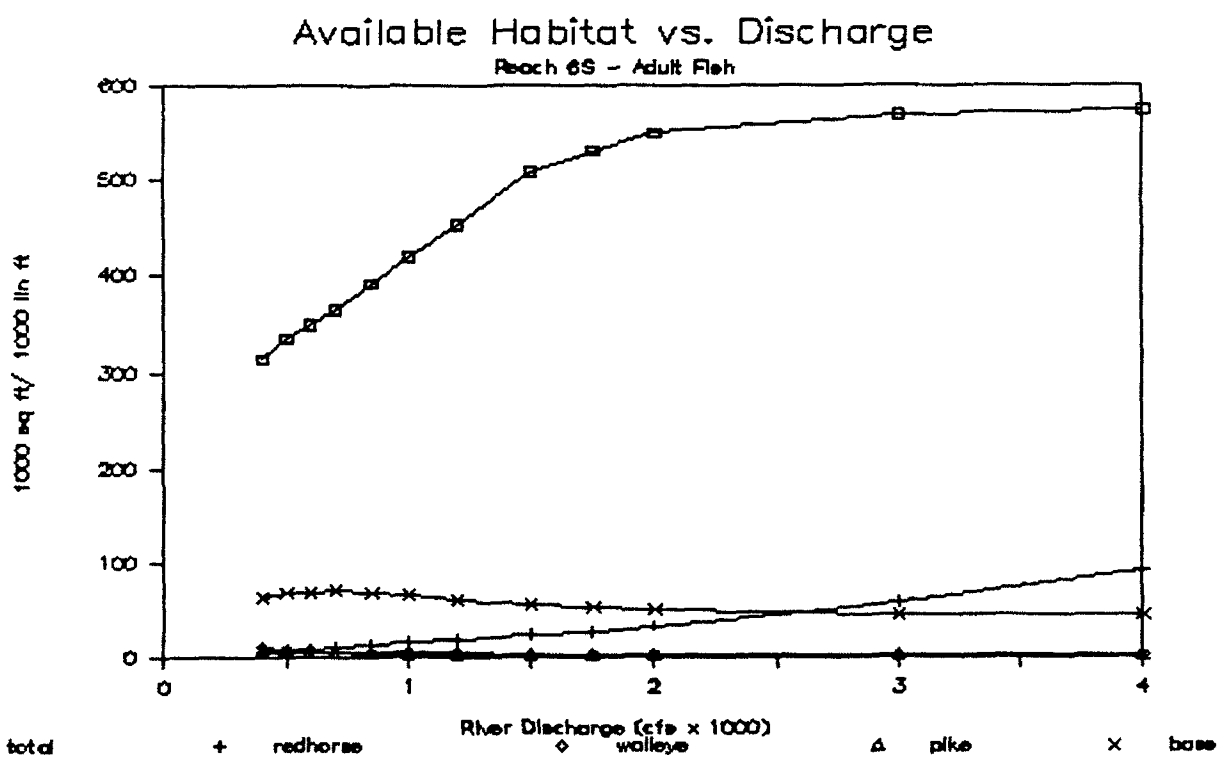
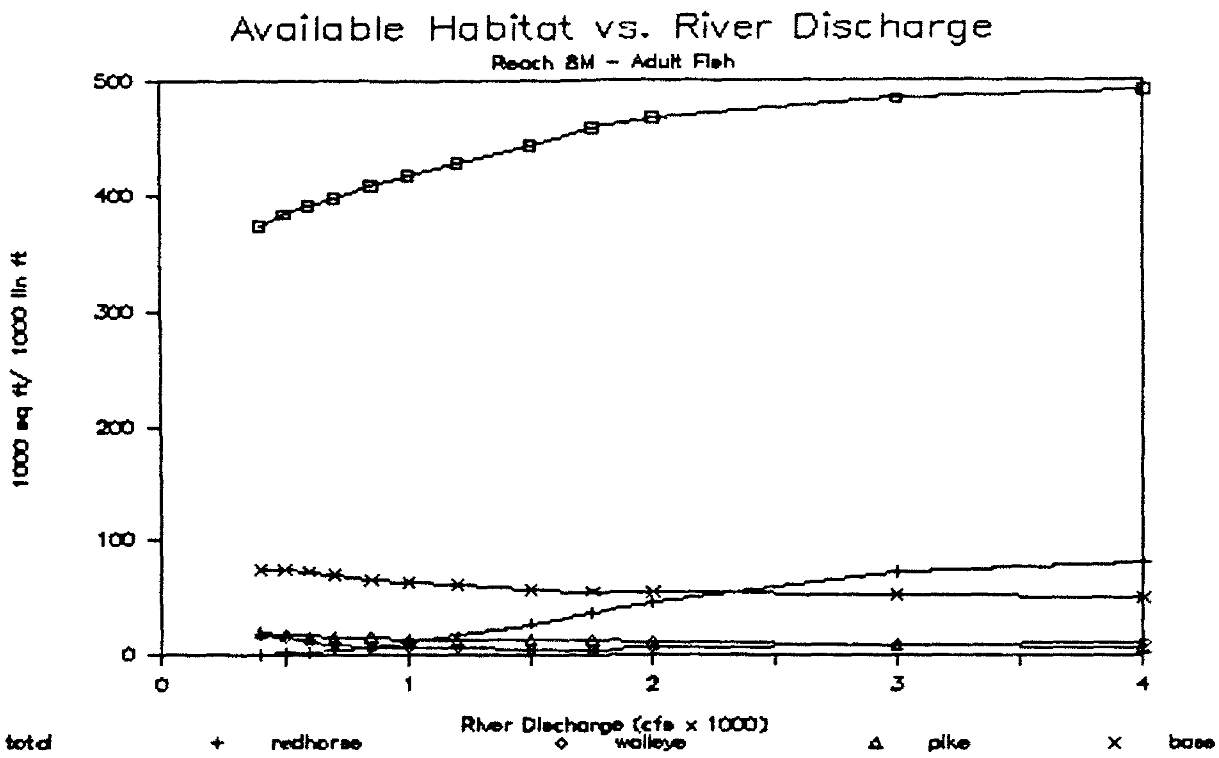


Figure E-13. Available habitat for adult fish vs. river discharge Mississippi River.



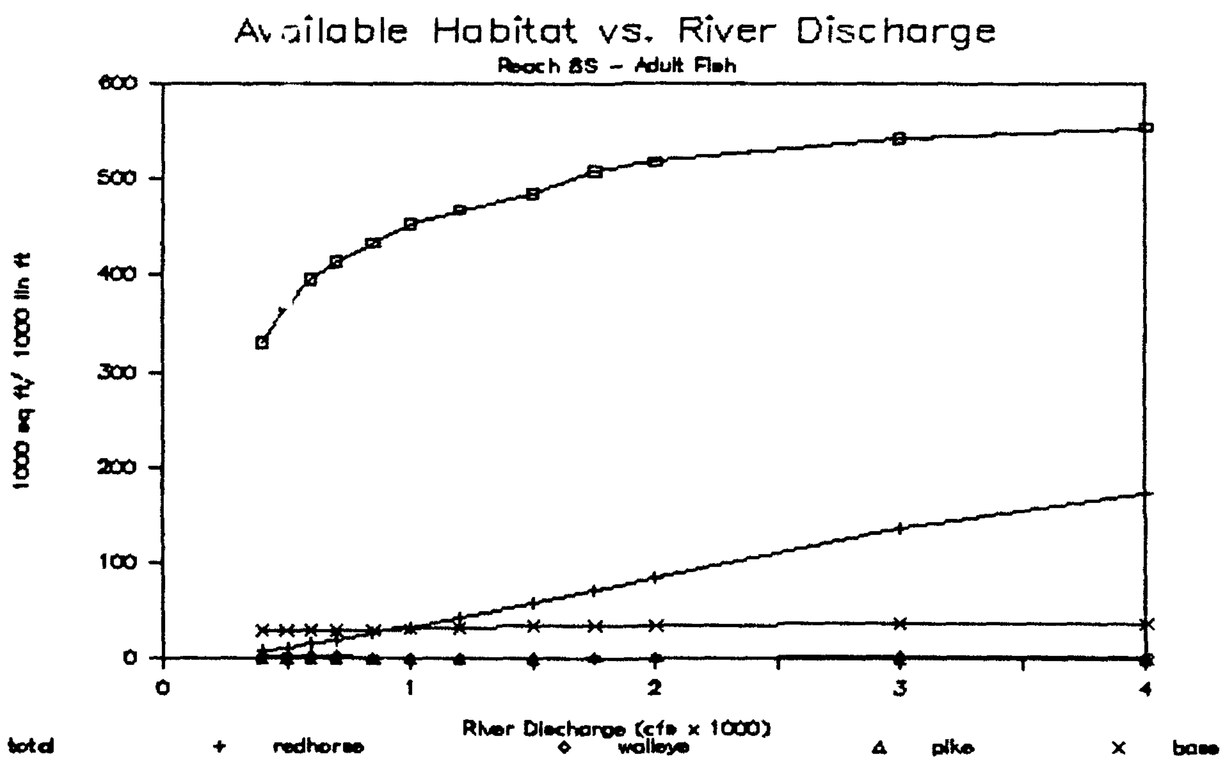


Figure E-14. Available habitat for adult fish vs. river discharge, Mississippi River.

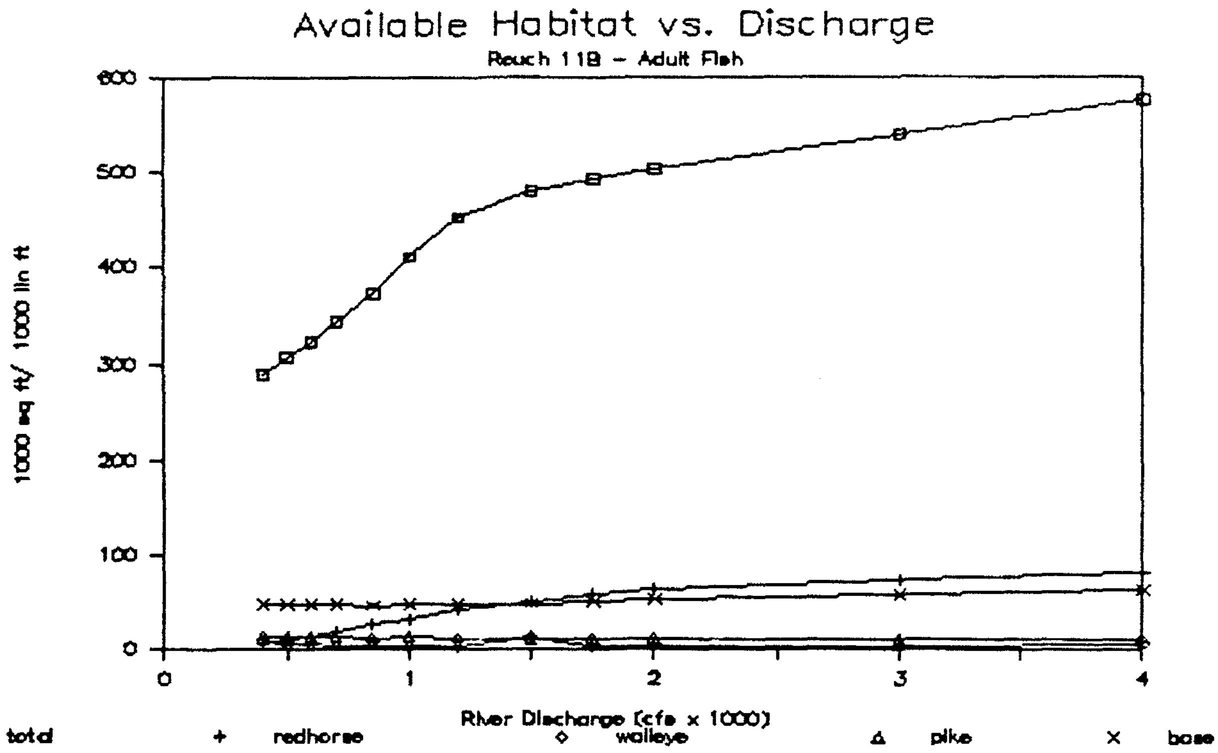


Figure E-15. Available habitat for adult fish vs. river discharge, Mississippi River.

approaching zero below 500 cfs. Habitat available for adult walleye and northern pike is predicted to be minimal at all levels of river discharge.

4.5 In the deep pool reach surveyed, with only fair hydraulic model calibration (4M), availability of suitable habitat for adult smallmouth bass, walleye, and northern pike is predicted to increase at discharge levels below 1,500 cfs, reaching maxima near the lowest simulated discharges of 400 to 500 cfs.

Habitat Available for Small Fish

4.6 Figures E-16 through E-19 illustrate results of IFIM modeling for selected small and young-of-year fish, using habitat suitability models developed by the MDNR Section of Fisheries. Because small and young-of-year fish can make greater use of shallow water, the model results indicate that these small fish can make use of a greater portion of the total river habitat than can larger fish at low levels of river discharge.

4.7 In the unbraided runs (reaches 6S, 8M, and 8S) with good hydraulic model calibration, simulated habitat available for a guild of small stream fish represented by banded darter is predicted to gradually decline with decreasing river discharge. The curve for darter guild habitat vs. discharge for the unbraided runs shows no inflection point. Predicted habitat availability for sand shiner and smallmouth bass young-of-year varied between reaches, and did not vary consistently between reaches at the extreme low end of the discharge range. Model results indicate that there is relatively little habitat available for walleye young-of-year in these river reaches at any discharge range.

4.8 In the island braided reach 11B, with good hydraulic model calibration, the simulated habitat available for the darter guild, sand shiner young-of-year, and smallmouth bass young-of-year all gradually declined with decreasing river discharge. Habitat available for young-of-year smallmouth bass was predicted to decline only slightly as river discharge declined to extreme low flow.

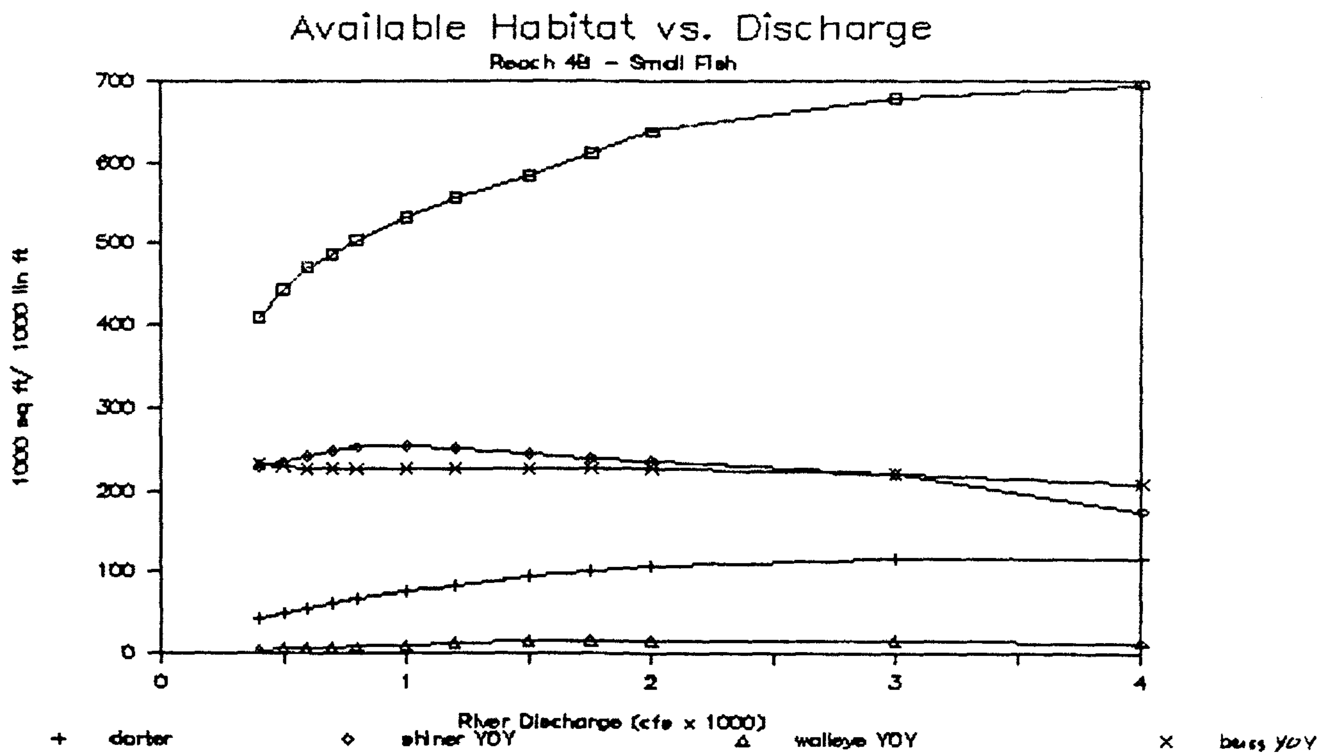
4.9 In the deep pool reach surveyed, with only fair hydraulic model calibration (4M), availability of suitable habitat for smallmouth bass young-of-year was predicted to increase to over half of the total river area at 400 cfs. Sand shiner young-of-year habitat was predicted to also be fairly widespread at low levels of river discharge. Habitat available for young-of-year walleye and the darter guild was predicted to be relatively scarce over the entire discharge range, with darter guild habitat showing a gradual decline at the lower discharge levels.

Habitat Available for Young-of-Year Smallmouth Bass

4.10 Habitat available for smallmouth bass young-of-year predicted using habitat suitability models derived from the Simonson and Swenson (1989) data gradually increases as discharge declines (figures E-20 through E023) with an indication of a reduction of available habitat below 500 cfs.

Recreation Conditions

4.11 The models of recreation conditions suitability predicted a definite increase in area suitable for canoeing with increasing river discharge (figures E024 through E-28). Conditions for canoeing were generally unsuitable at river discharge levels below about 600 cfs, with sandbars and



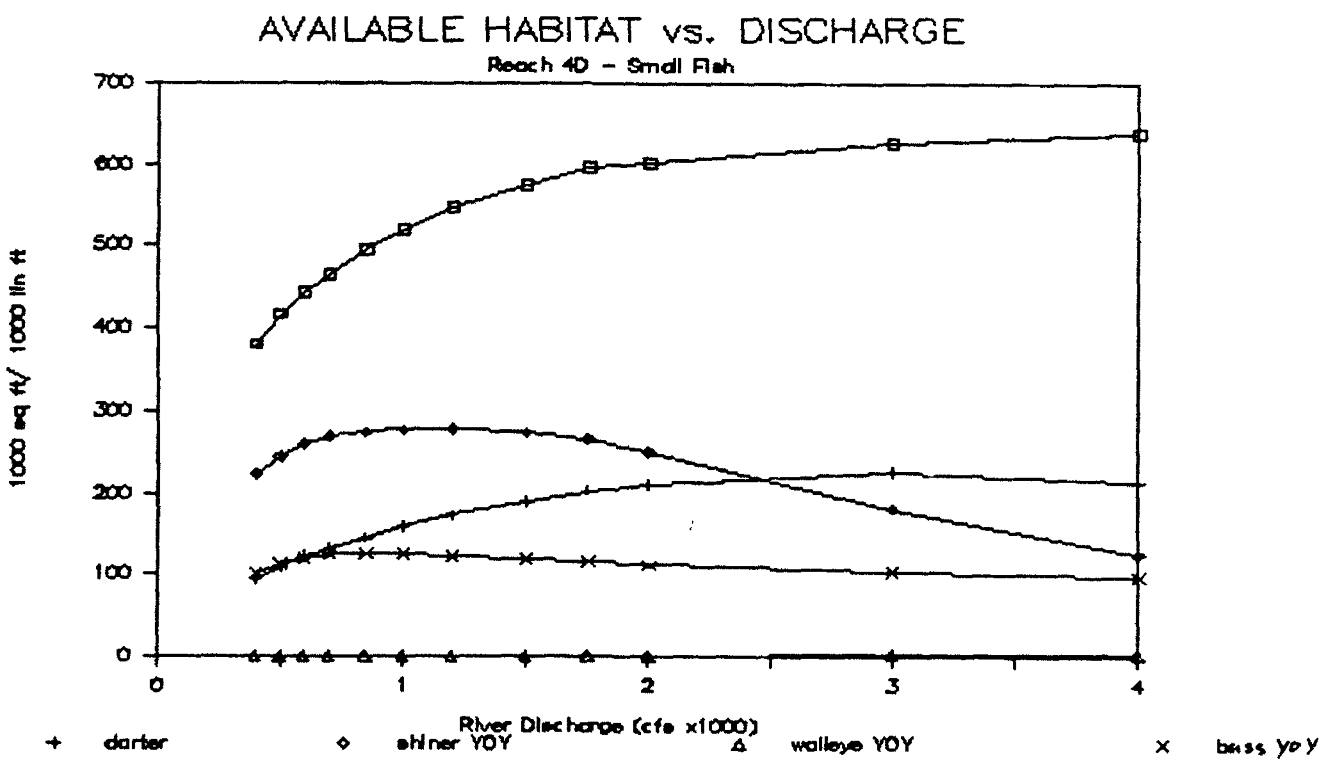
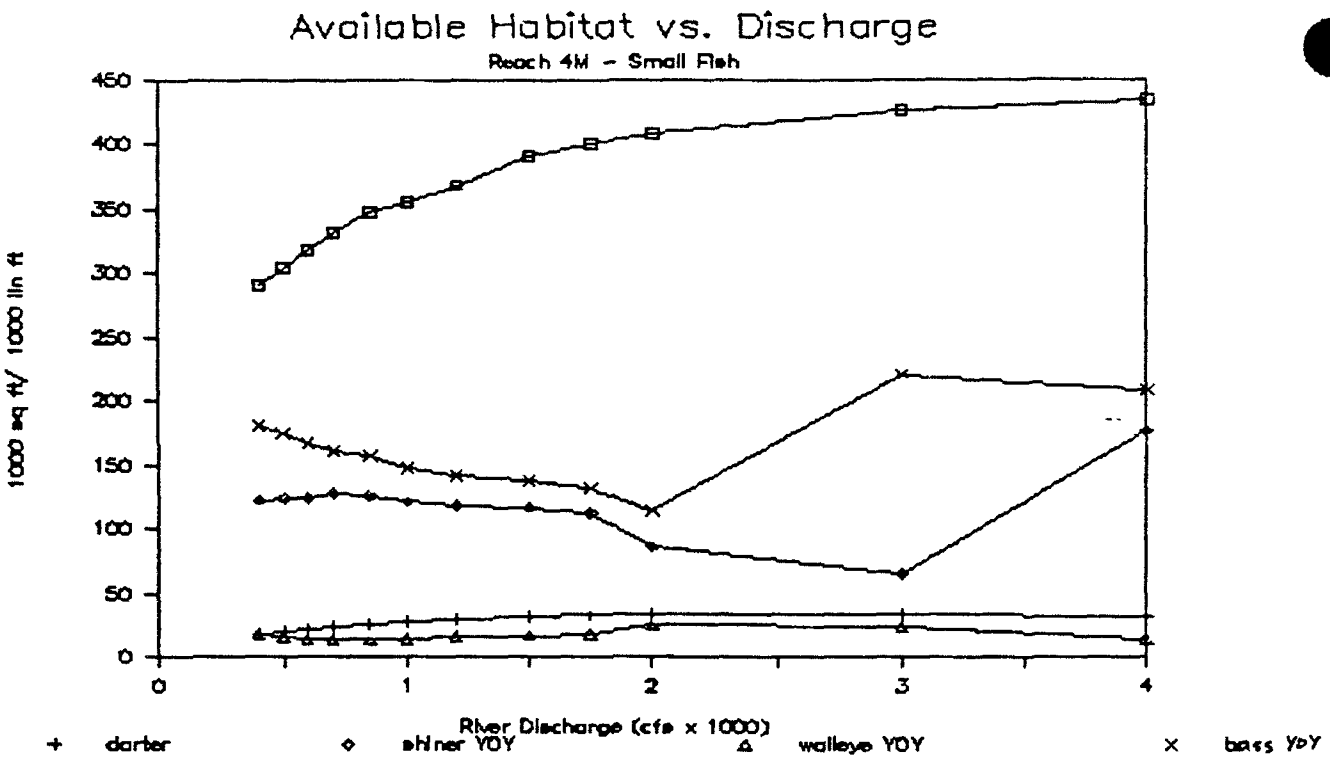


Figure E-16. Available habitat for small and young-of-year fishes in the Mississippi River.



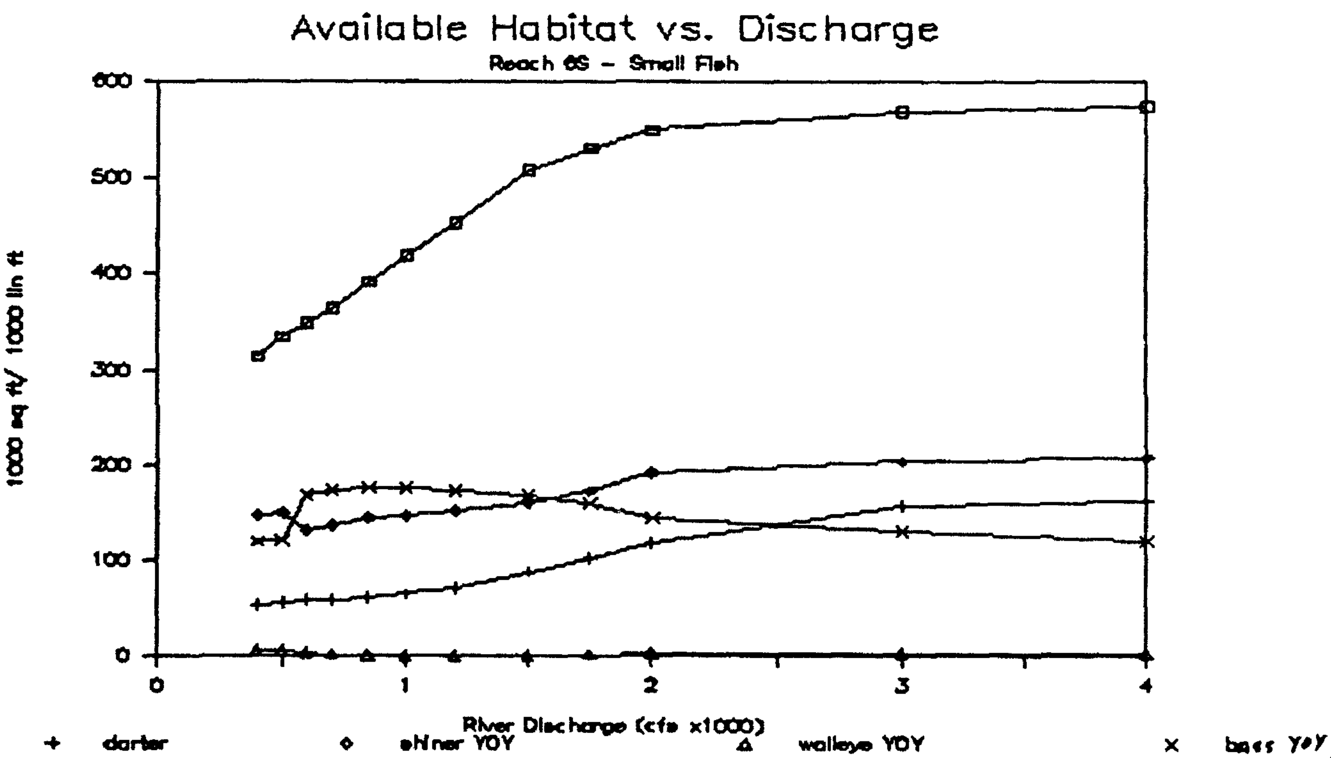
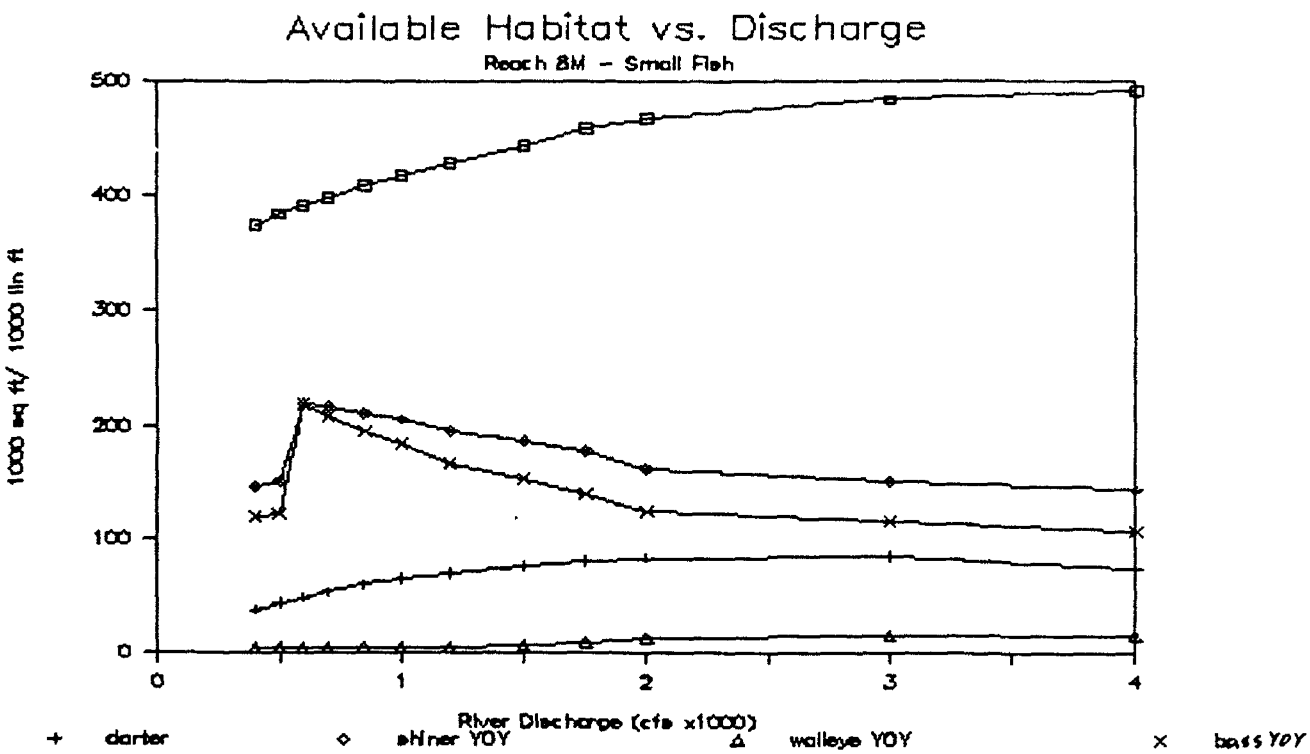


Figure E-17. Available habitat for small and young-of-year fishes in the Mississippi River.



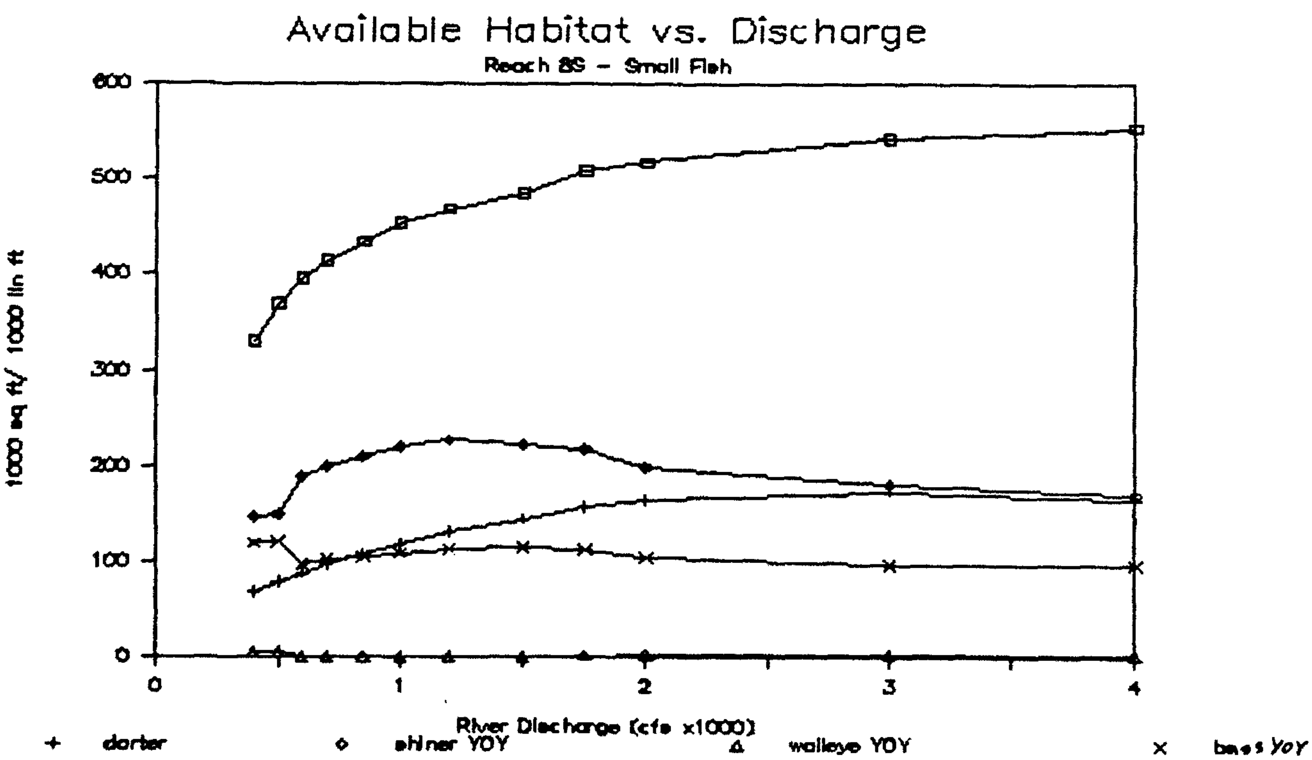


Figure E-18. Available habitat for small and young-of-year fishes in the Mississippi River.

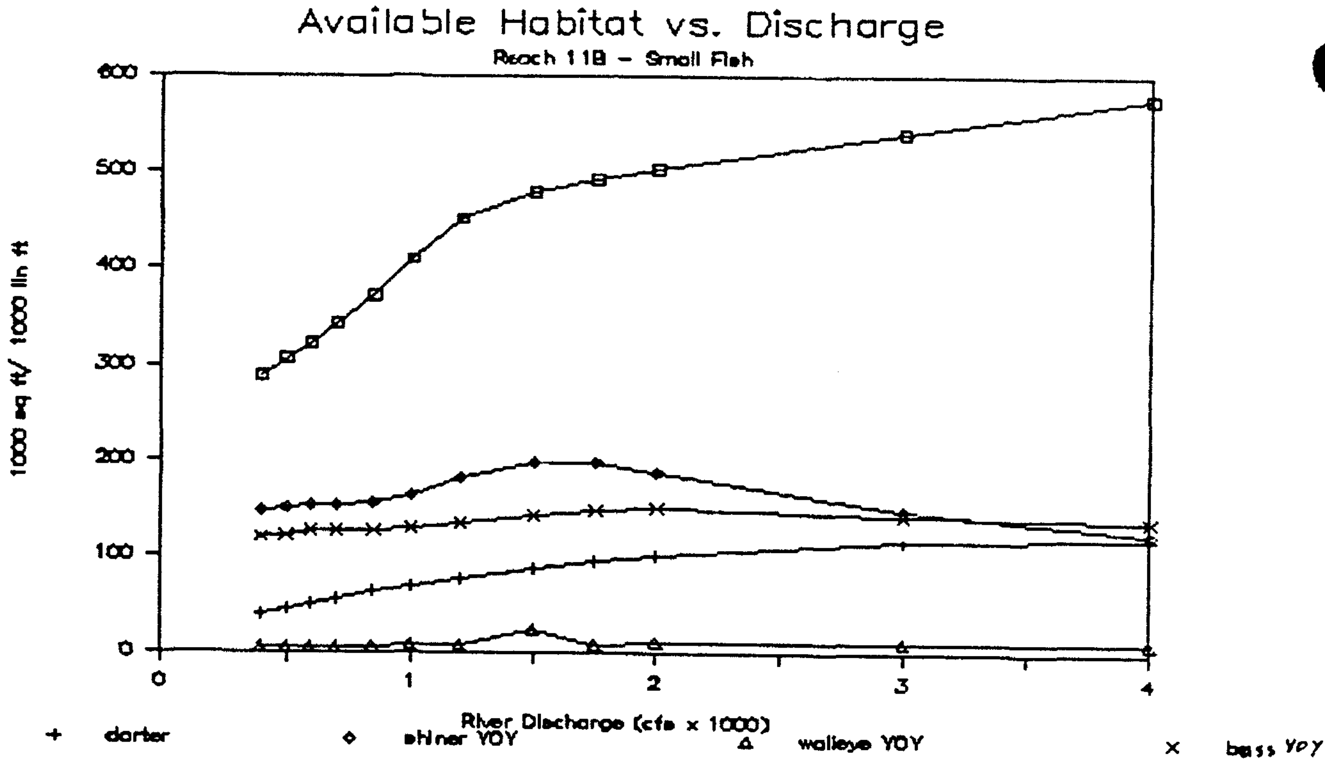
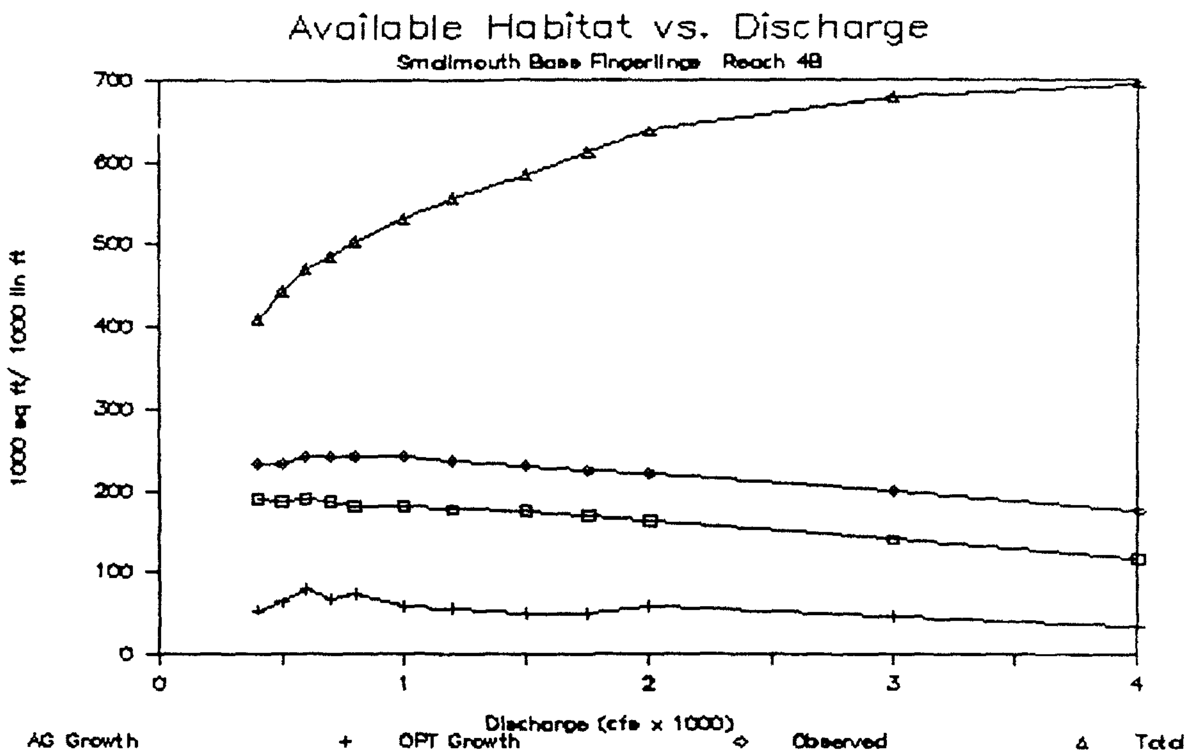


Figure E-19. Available habitat for small and young-of-year fishes in the Mississippi River.



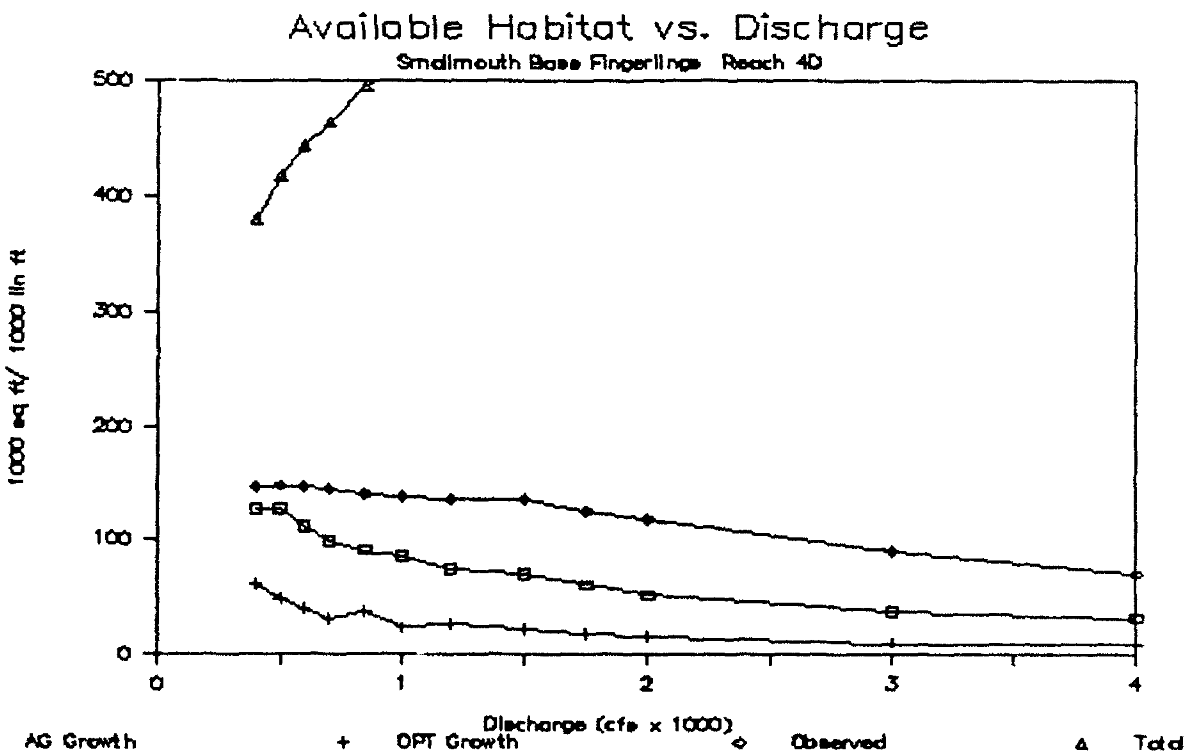
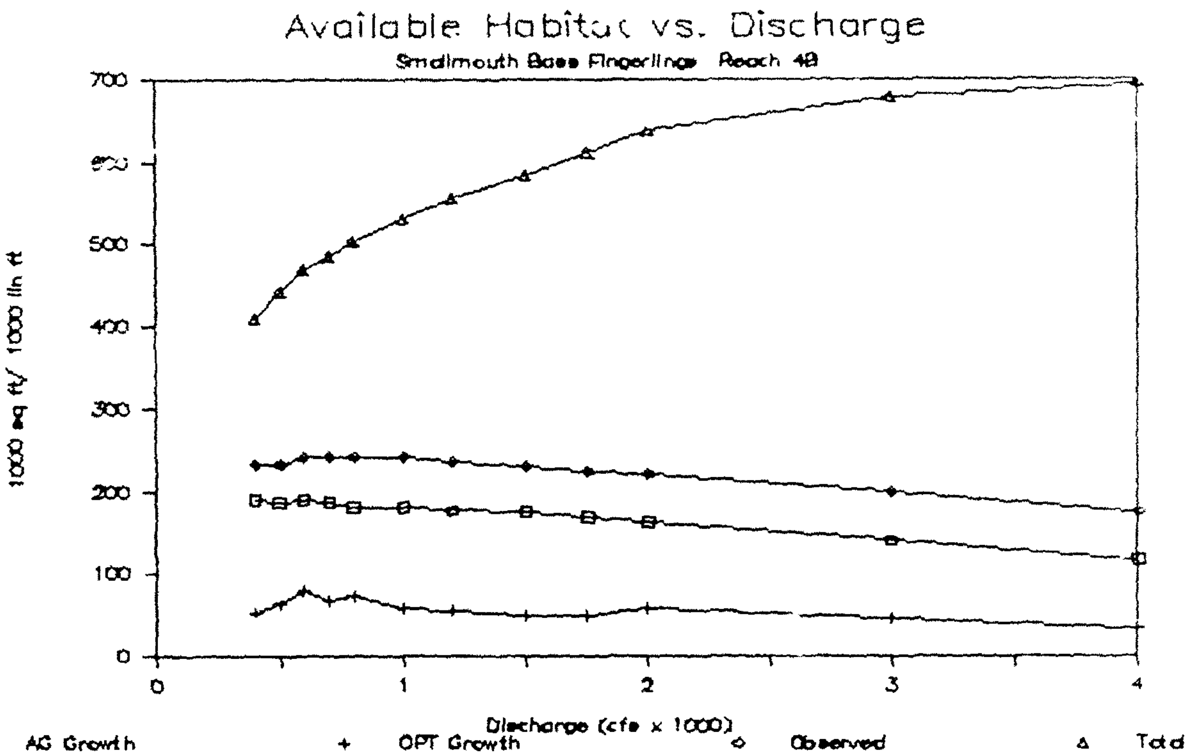


Figure E-20. Available habitat for smallmouth bass young-of-year in the Mississippi River.



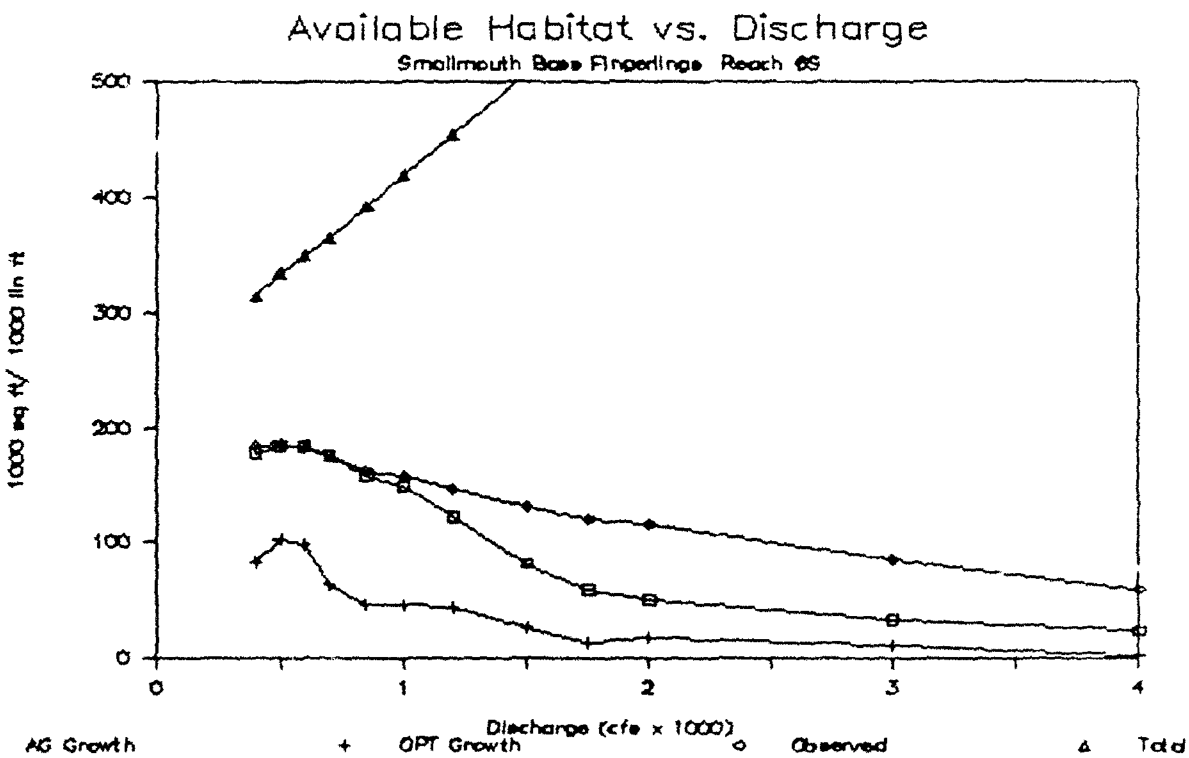
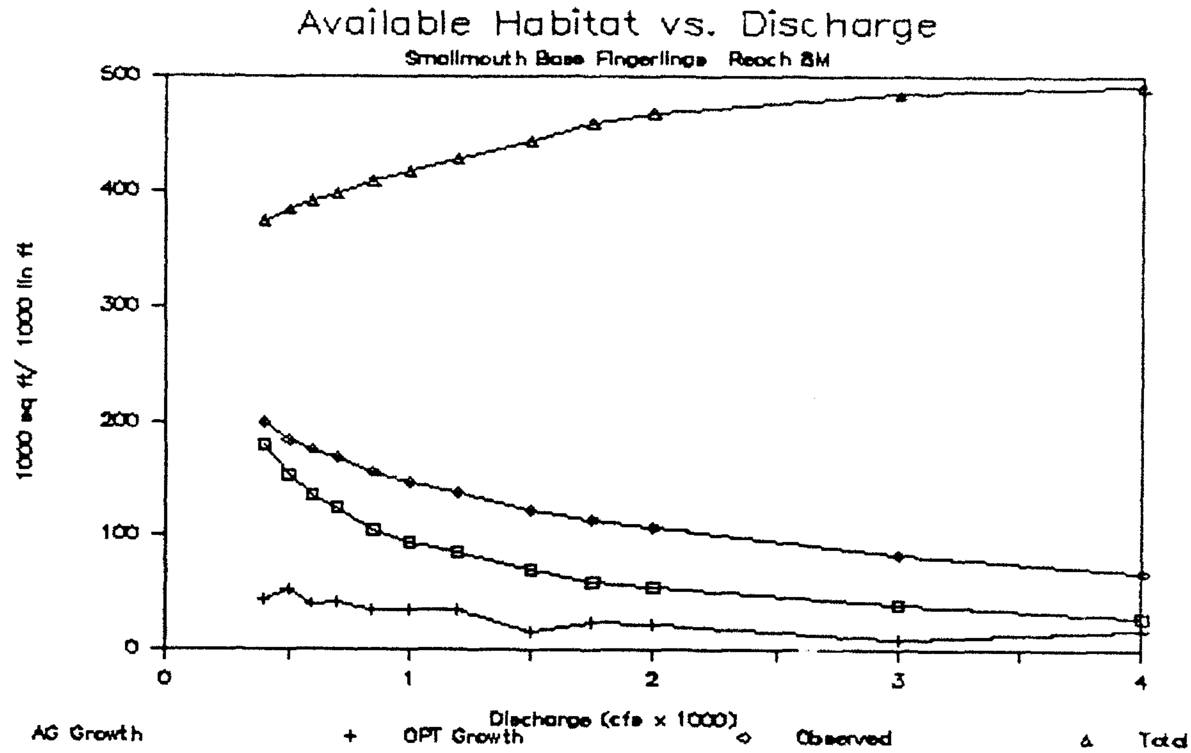


Figure E-21. Available habitat for smallmouth bass young-of-year in the Mississippi River.



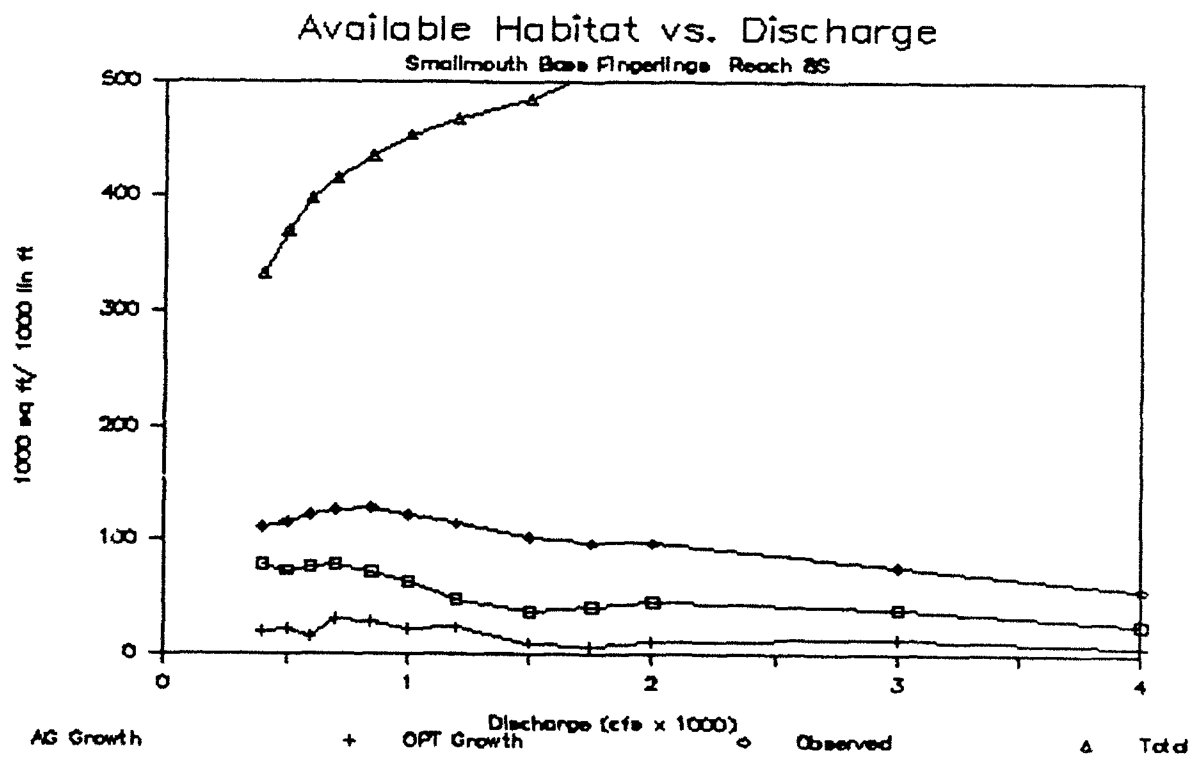


Figure E-22. Available habitat for smallmouth bass young-of-year in the Mississippi River.

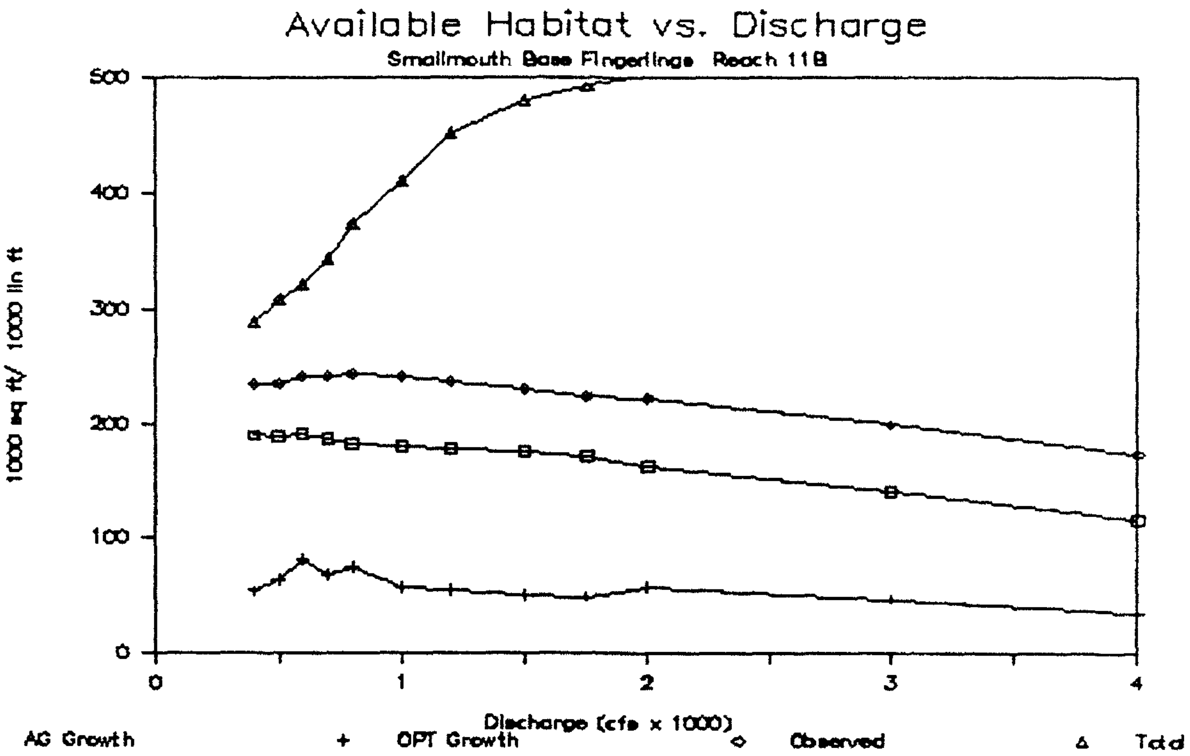
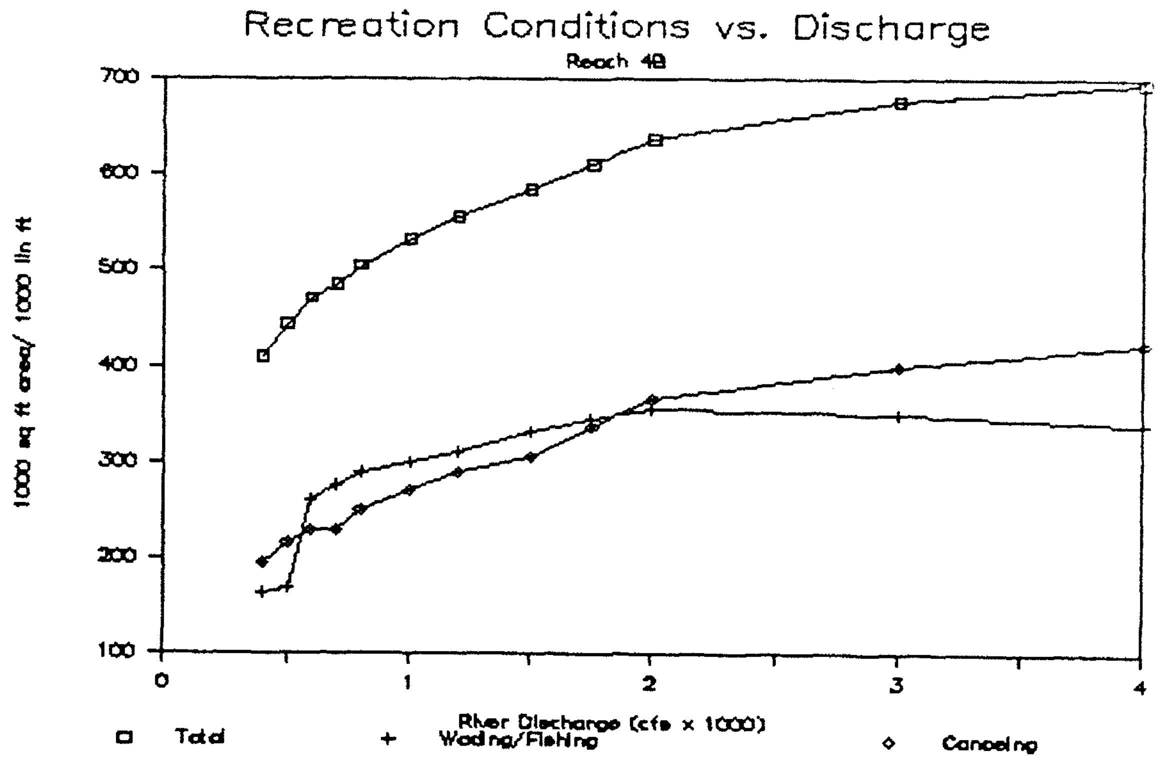


Figure E-23. Available habitat for smallmouth bass young-of-year in the Mississippi River.



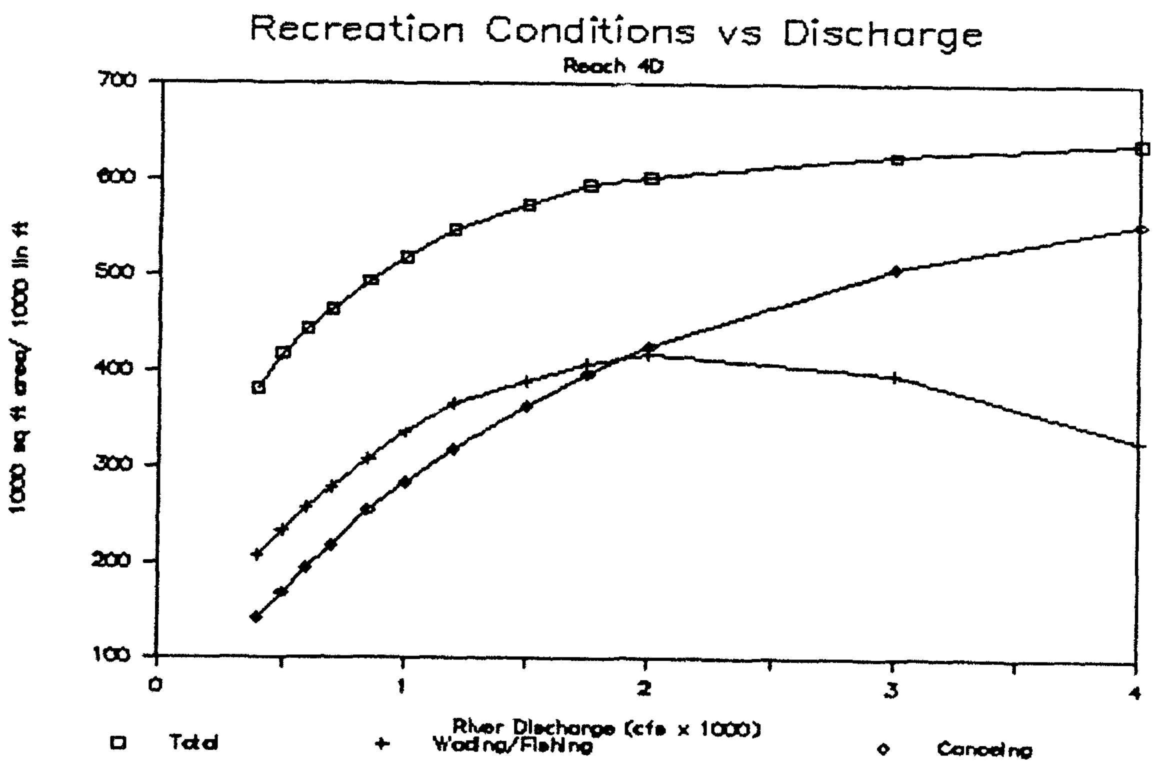
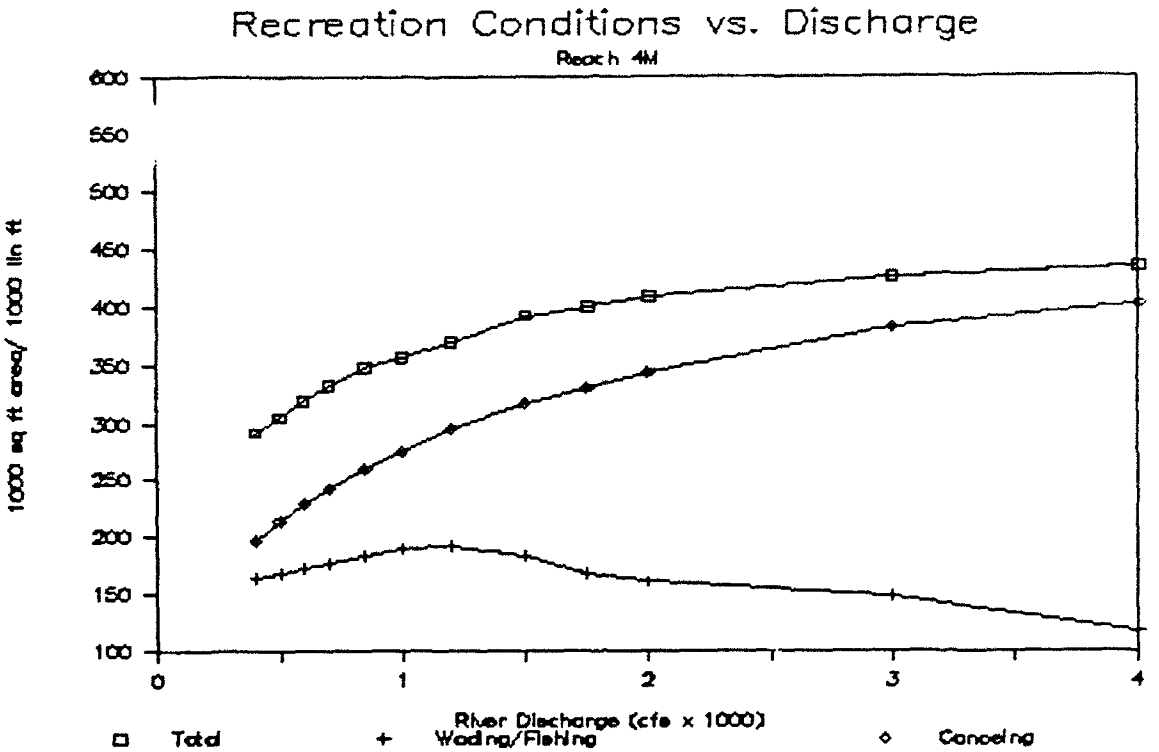


Figure E-24. Suitability of conditions for wading/fishing and canoeing in the Mississippi River.



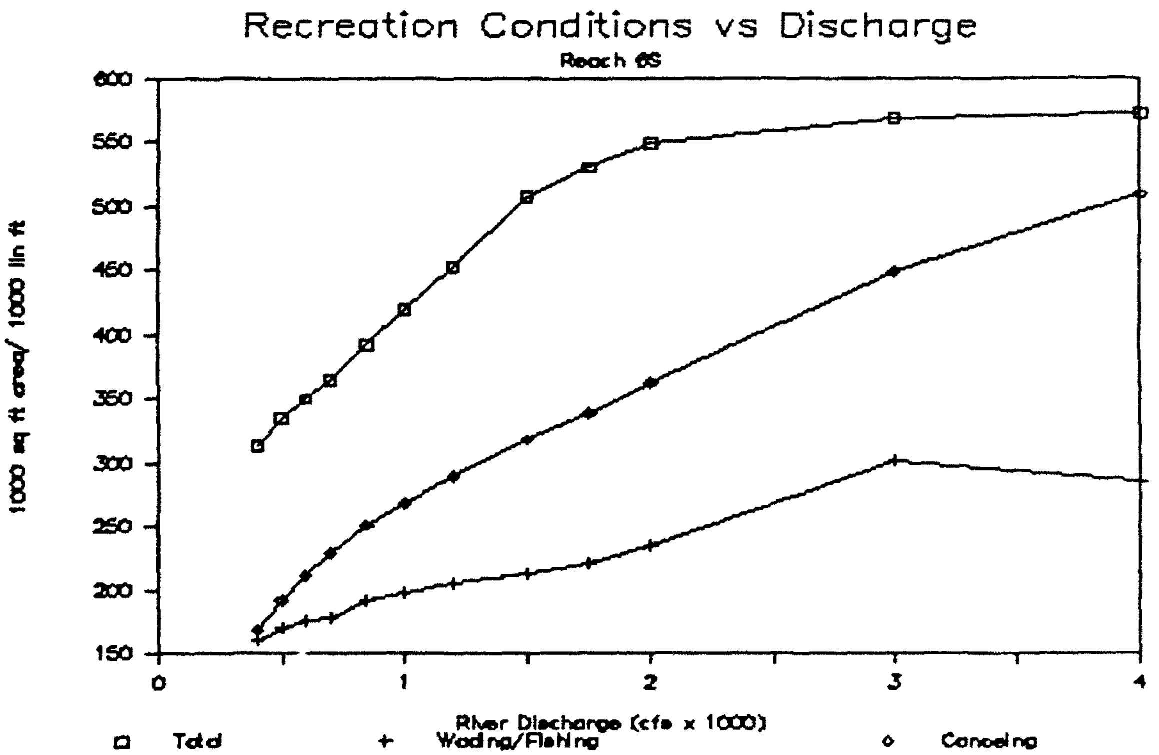
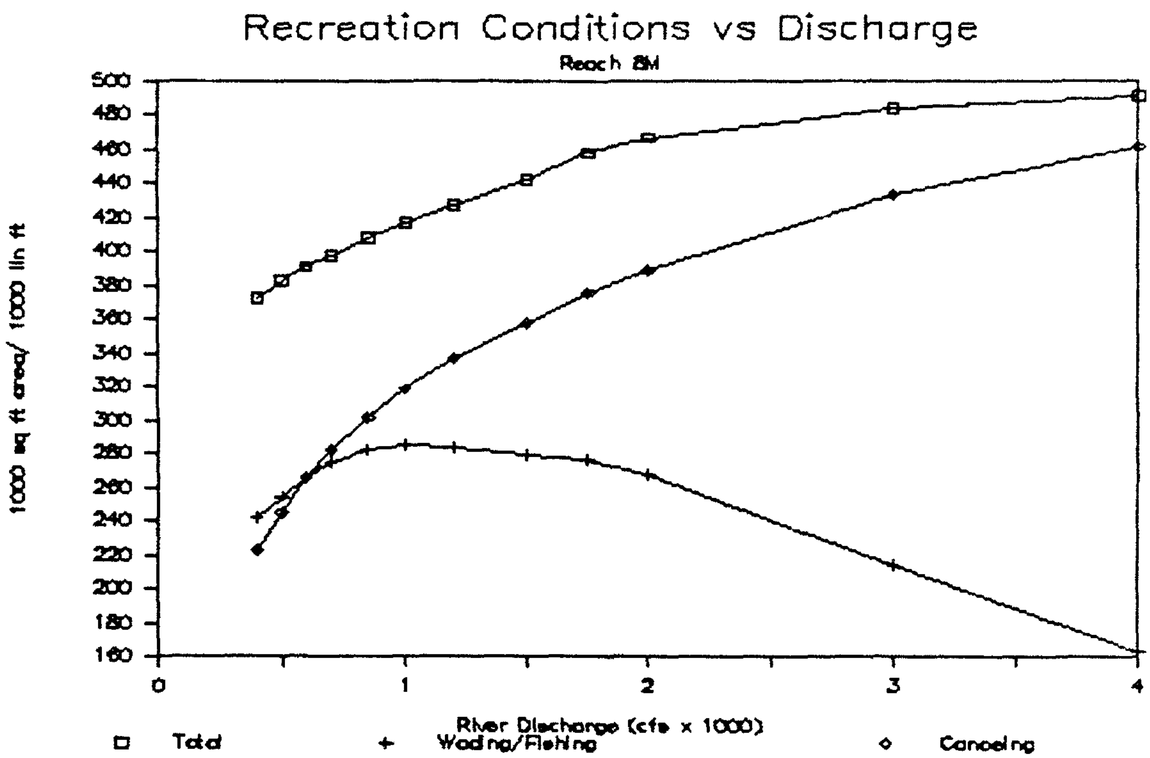


Figure E-25. Suitability of conditions for wading/fishing and canoeing in the Mississippi River.



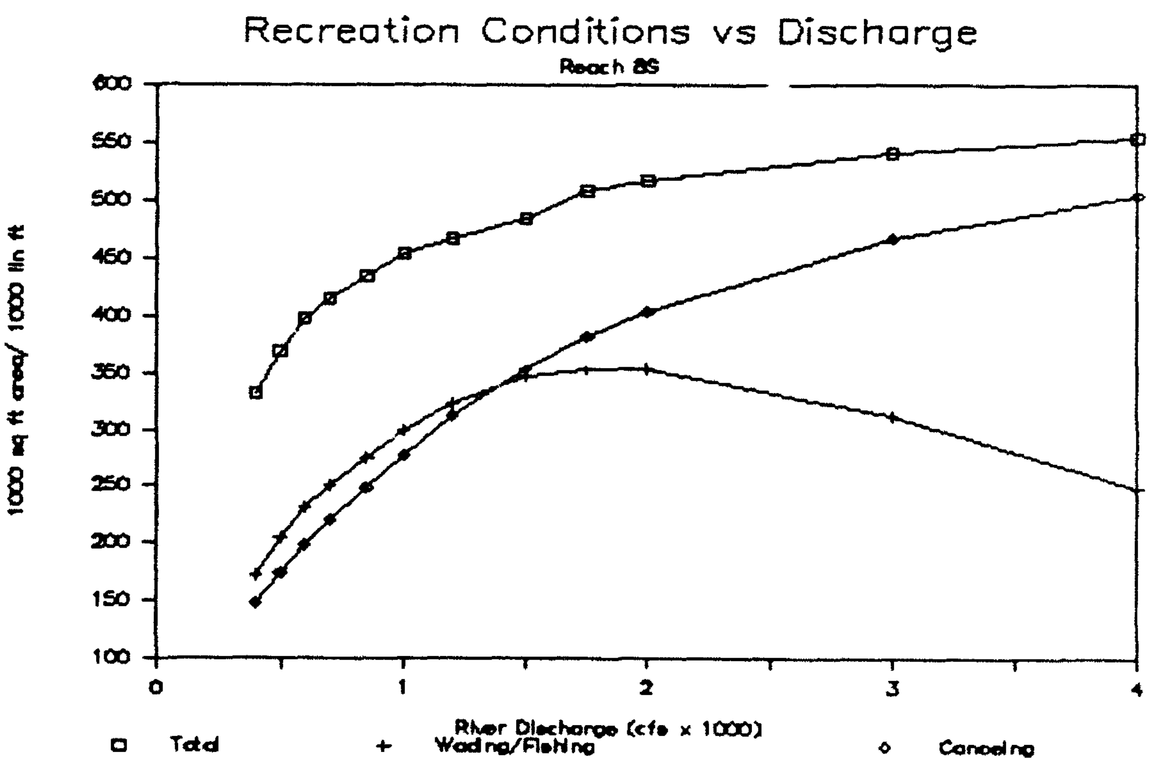
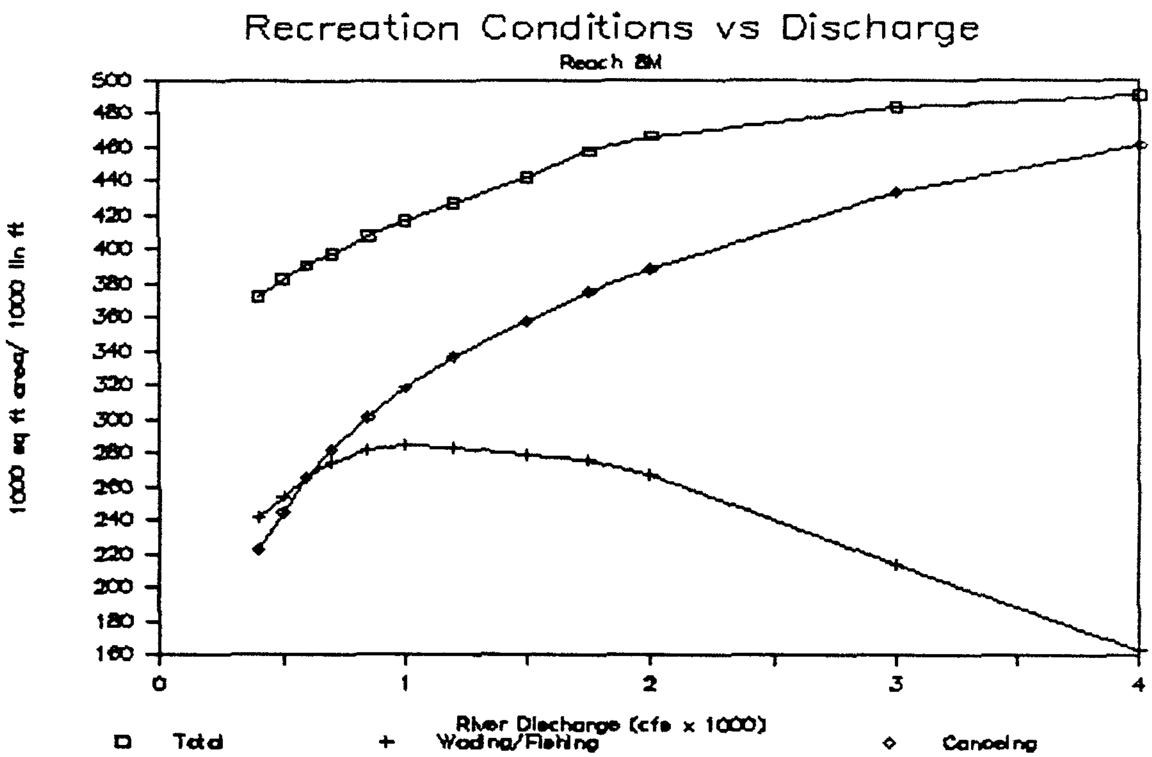


Figure E-26. Suitability of conditions for wading/fishing and canoeing in the Mississippi River.



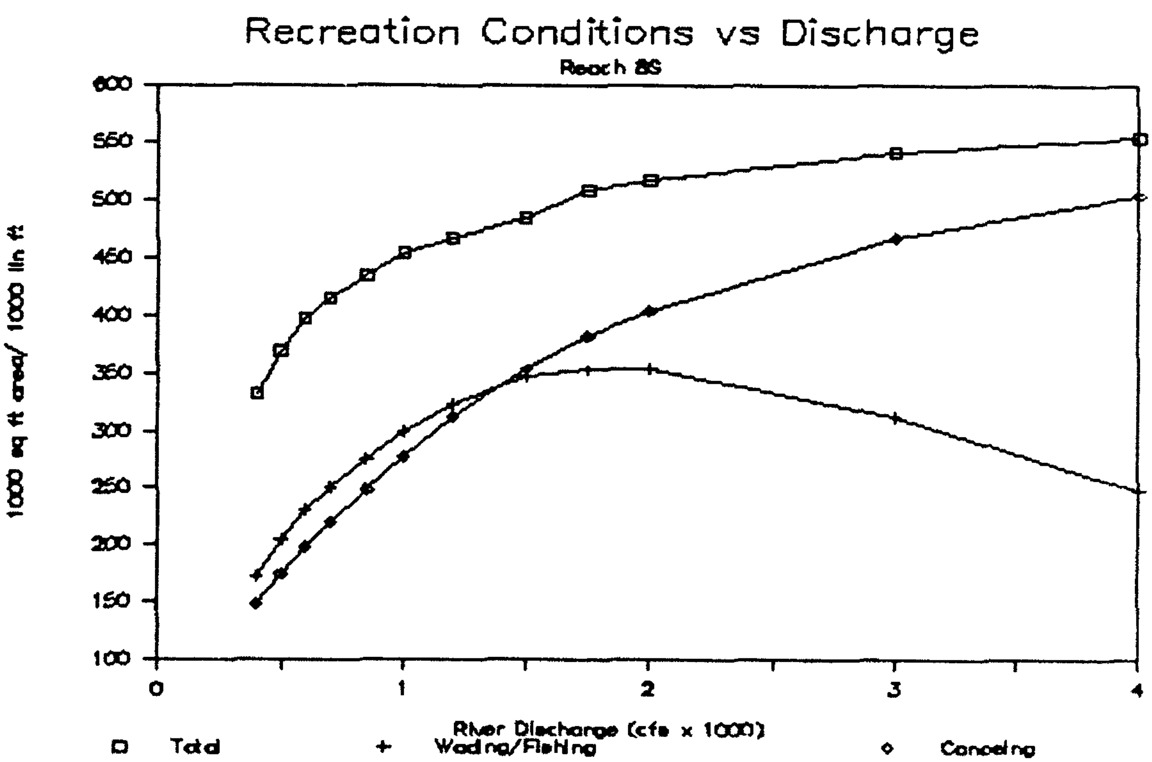


Figure E-27. Suitability of conditions for wading/fishing and canoeing in the Mississippi River.

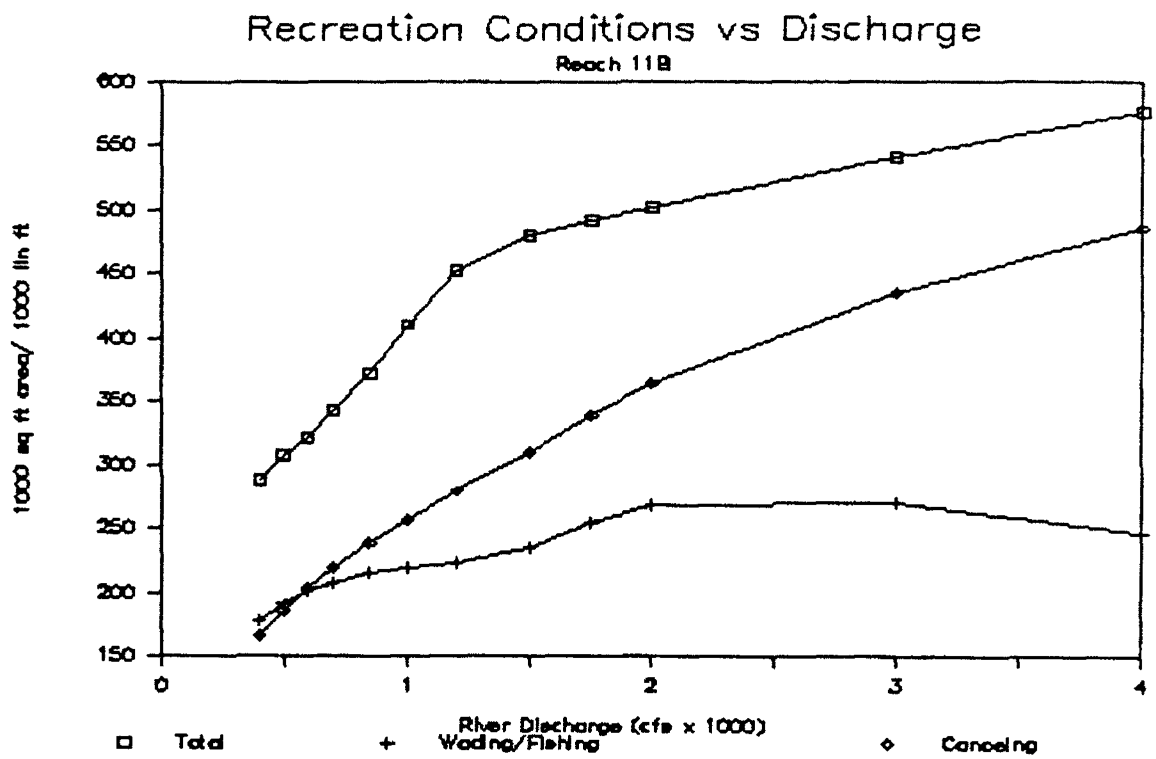


Figure E-28. Suitability of conditions for wading/fishing and canoeing in the Mississippi River.

riffle areas presenting obstacles. Conditions for wading/fishing were predicted to be optimal at 1,000 to 2,000 cfs for most reaches, and declining at lower levels of river discharge.

Discussion

Effects of Low Flow on Wetted Perimeter

5.0 The 7-day, 10-year (7Q10) low flow for the study reach, measured at Elk River, is 874 cfs (table E-2). At this level of river discharge, sufficient depth of water remains to provide cover for fish in pools. About two-thirds to three-fourths of riffle substrate is wetted. There is sufficient depth of water in the riffle areas to allow movement of fish between pools. Most of the channel border embayments and secondary channels are dewatered. Current velocity is reduced. Water temperature very closely follow air temperature.

5.1 At extremely low levels of river discharge, such as occurred in 1988, discharge through the study reach was as little as 724 cfs daily average, gaged at the Monticello Nuclear Power Plant. The 1-day, 100-year low flow at Elk River is estimated to be 357 cfs. At 400 cfs or less, very little of the study reach has water depth greater than 1.5 feet. There are lengthy shallow areas between pools that with insufficient depth of water to provide cover for large fish. Only about half of the riffle substrate are wetted. Velocities are minimal. Water temperature closely follows air temperature, attaining maximum.

Effects of Low Flow on Aquatic Life

5.2 As river discharge declines toward extreme low flow, the volume of available habitat is reduced and water quality conditions become more stressful in aquatic life. Diel swings in water temperature and dissolved oxygen become more pronounced. Fish density is increased by reduced volume of habitat in the river and influx of other fish from shrinking tributary streams. Predation is greater because of the higher density of fish in the remaining habitat. Food production in the stream may be reduced by the desiccation of riffle areas but this may be offset by the luxuriant growth of periphyton that is stimulated by low flow conditions. Shallow abandoned channel embayments and side channels become isolated from the main channel of the river, stranding fish and denying access to these valuable habitat areas. Exploitation of fish by anglers and fish-eating birds is increased because of the shallower river and concentration of fish in remaining habitat.

5.3 Lotic species of fish which prefer higher current velocity, such as shorthead redhorse, have greatly reduced area of suitable habitat. Lentic species of fish, such as smallmouth bass, have expanded habitat available due to the reduced current velocities. At the lowest levels of river discharge, habitat with sufficient water depth to provide cover may become limiting for adult fish. Most young-of-year fish, which require low current velocity habitat, have expanded areas of habitat available at low levels of river discharge. The extensive shallow flats and periphery of riffle areas provide protection from predation by larger fish, but increase vulnerability of fish to predation by fish-eating birds.

5.4 Research by Swenson et al. (1981), Swenson et al. (1983), Simonson and Swenson (1989), and monitoring by Northern States Power Company (1989)

indicate that low river discharge has a positive effect on smallmouth bass reproductive success and recruitment. The preliminary results of Simonson and Swenson (1989) showed that feeding activity, energy gain, and respiration cost for fingerling smallmouth bass reached the optimum for growth at the fairly low current velocity range of 80-120 mm/sec. These low current velocities are prevalent during periods of low river discharge. Monitoring by NSP has documented good recruitment by smallmouth bass in years with low river discharge.

5.5 Other forms of aquatic life are also affected by low levels of river discharge. Stream productivity may be reduced by the generally lower nitrogen and phosphorus concentrations that occur during low flow periods due to reduced surface runoff inflow. High temperatures and low current velocities, on the other hand, allow luxuriant growth of periphyton on the stream bottom. Drift of particulate organic matter is reduced by the greatly diminished surface runoff and tributary inflow. Food available for filter-feeding macroinvertebrates may be greatly reduced. Fine-grained sediments and particulate organic matter accumulate on the stream bottom in areas that are normally swept clear by current, increasing deposition of food materials for detritus-feeding macroinvertebrates. During sustained low river discharge periods, aquatic macrophyte growth is encouraged by the improved light penetration and reduced velocity. At extremely low river discharge levels, however, most clumps of macrophytes along the channel margins and macrophytes growing in off-channel areas are desiccated.

5.6 As flows diminish toward extreme low flow, the wetted riffle areas shrink significantly, stranding macroinvertebrates and forcing a concentration of animals toward the center of the channel or downstream by drifting. Mussels may become stranded if discharge falls off rapidly.

5.7 Direct observation of the 1988 extreme low flow conditions in the Mississippi River by MDNR fisheries managers did not reveal any fish kills or evidence of excessive stress on fish. Angler exploitation was high, but the fisheries managers did not indicate that excessive exploitation occurred.

<u>Effects of Low Flow on Wildlife</u>

5.8 Low levels of river discharge greatly reduce shallow aquatic and wetland habitat available for wildlife. Dewatered abandoned channel lakes, side channels, and embayments still provide terrestrial wildlife habitat with some value. Dewatering of normally-inundated riverine wetlands has the beneficial effect of stimulating germination of emergent aquatic plants. Fish-eating birds and mammals benefit from fish being increasingly concentrated in shallow areas. Bank-denning animals lose the protection afforded by water adjacent to dens.

<u>Effects of Low Flow on Recreational Use</u>

5.9 Boating on the unimpounded reaches of the Mississippi River upstream of the Twin Cities metropolitan area becomes increasingly difficult as river discharge declines. Boat launching ramps built for normal river stages become unusable for heavier trailered boats. At discharge levels less than about 600 cfs in the study reach, canoeing requires considerable walking and dragging of canoes over shallow sandbars and riffles. Wading anglers find easier conditions with improved water clarity, lower current velocity, concentrated fish, and more access during low flow periods. During extreme

low flow conditions, fish become increasingly concentrated in the few remaining deep areas, providing fishing but requiring lengthy hikes between fishing holes. Extended periods of low river discharge allow development of thick mats of periphyton which can make wading hazardous.

Conclusions

Adequacy of Instream Flow Modeling of the Study Reach

6.0 The hydraulic survey data upon which the models were based was collected in 1980. We have confidence in the accuracy of the hydraulic survey data. A number of bank-full flow periods have occurred since the surveys were conducted, probably resulting in some alternation of river geometry at the surveyed cross sections. The hydraulic survey data collected in 1980 remains representative of the study reach of the river, however. Velocity measurements were made at two relatively similar levels of river discharge, rendering hydraulic model calibration difficult, and limiting confidence in the results for several of the modeled reaches. The habitat suitability models available are well-suited to assess instream flow needs for the Mississippi River during the growing season. No models are currently available that incorporate winter habitat requirements or habitat requirements for aquatic life forms other than fish. There is a need for better predictive certainty for the extreme low end of the discharge range, where model results will provide valuable information for future decisions about river regulation during drought.

Adequacy of Headwaters Low Flow Release Rate During Normal Conditions

6.1 The instream flow analyses presented above indic... that river discharge of 1,600 to 2,000 cfs may be optimal for aquatic life in the river during the growing season, by providing completely wetted riffle areas, without excessive velocities. At this range of river discharge, there is sufficient water in the river to provide considerable habitat for most species and life stages of fish and to support recreational boating and fishing. It is not known to what extent this range of river discharge provides for water in off-channel shallow aquatic and wetland areas that are valuable wildlife habitat and fish nursery areas.

6.2 Winter habitat requirements are not known. It may be possible to improve winter habitat conditions in the river through careful regulation, especially by avoiding increases in discharge during the winter months that could stress overwintering fish and disturb denning furbearers.

6.3 The routine low flow releases from the headwaters lakes appear to be adequate for the study reach during normal conditions. The 7Q10 discharge at Elk River, the downstream end of the study reach, is 874 cfs. Of the 270 cfs routine low flow release from the headwaters lakes, perhaps 200 cfs, or 70 to 80 percent after travel losses, enters the study reach. Thus, during low flow conditions near the 7Q10 flow, approximately 25 percent of the discharge is contributed by releases from the headwaters lakes. There is sufficient volume of habitat remaining in the river at the 7Q10 flow rate to maintain fish and other aquatic life. Water quality is not a significant problem. there are some beneficial aspects to occasional low flow years, such as improved recruitment of smallmouth bass, germination of emergent aquatic plants in adjacent wetlands, and improved sport fishing opportunity.

Adequacy of Headwaters Low Flow Release Rate During Drought

6.4 During drought, river discharge will fall below the 7Q10 flow of 874 cfs at Elk River for extended periods. The average July flow during the 1988 drought was 867 cfs at the Monticello Nuclear Generating Plant (Orr 1989). Flows during the worst of the drought in 1988 were record or near-record minimums (353 cfs released from the dam at Sartell on July 27; 656 cfs gaged at the Monticello Nuclear Generating Plant on July 28; and 842 cfs on July 20 at Anoka).

6.5 It appears that flows as low as occurred in 1988 are sufficient to maintain aquatic life in the study reach without long-term damage. Fisheries managers did not observe any fish kills or mention any indications of excessive stress on fish populations. Continued monitoring of fish populations near the Monticello and Sherco power plants by Northern States Power Company will reveal the effects of the 1988 drought on fish year class strength and growth in the study reach.

6.6 Recurrence of drought conditions in successive years (such as occurred in the 1930's) would effectively reduce the size of the river and its carrying capacity for aquatic life. It is unlikely that increased releases from the headwaters lakes could be of sufficient discharge and duration to have a significant effect on the condition of the aquatic community in the study reach during an extended drought.

Adequacy of Reduced Drought Release Rate From Headwaters Lakes

6.7 The existing operating plan for the headwaters lakes calls for maintaining the routine low flow rate of release (270 cfs) until the individual lake stages fall below set levels. After the lakes fall to below these unacceptably low levels, releases are scheduled to be reduced by half. This contingency has never been carried out. The routine low flow rate of release of 270 cfs was maintained throughout the droughts of 1976 and 1988. In the event of a more sever future drought, the agency consultation process (described in Appendix D) may result in a different strategy for long-term releases from the headwaters lakes. It would be a severe shock to the already-stressed aquatic life in the river to cut releases from the headwaters lakes by as much as half due to low lake levels. Some stepped-down plan for releases should be considered to minimize impacts to aquatic life. Such a stepped-down plan could be implemented through interagency coordination anyway, to meet other water use demands.

Recommendations

Need for Instream Flow Needs Analysis for Upstream Reaches

7.0 Only about 25 percent of the 7Q10 flow in the St. Cloud to Elk River study reach is provided by low flow releases from the headwaters lakes. Releases from the headwaters lakes provide a much greater percentage of low flow discharges to the Mississippi River upstream of the study area. Many miles of high quality s ream habitat are much more sensitive to minor changes in river discharge than the present study reach. There is a clear need for instream flow needs assessments for Mississippi River reaches closer to headwaters ares. We recommend that representative reaches be selected from morphologically different river reaches, that the river reaches be mapped according to habitat types, and that instream flow needs be assessed for each habitat type within the selected reaches. Focus of attention should be prediction of habitat availability at the extreme low

end discharge range. Hydraulic survey and hydraulic modeling effort should be directed toward gaining predictive certainty at low discharge levels.

Need for Assessment of Winter Habitat Requirements

7.1 There is a need to determine winter habitat requirements of aquatic life and to regulate the river to minimize impacts during the winter months when fish are most vulnerable to discharge fluctuations. We recommend that winter habitat requirement be incorporated into the instream flow needs analysis of the upstream reaches.

Needs for Assessment of Macroinvertebrate Habitat Requirement

7.2 There is a need to also consider macoinvertebrate habitat requirements is assessing instream flow requirements for the Mississippi River because of their abundance and their importance to the ecology of the Mississippi River. IFIM model development macroinvertebrate suitability could be conducted after Gore (1987).

Need for Stepped Reduction of Low Flow Releases

7.3 n the event of protracted drought, any reduction of the routine low flow rate of release from the headwaters lakes should be gradual, to minimize impacts on aquatic life in the river. However, the low flows should not be overly extended in such a way to unnessarily lower project lake levels at extremely low lake levels, considerations other than instream flow needs may temporarily override the low flow decision process.

Need for Applying a Systematic Method for Assessing IFIM Model Results

7.4 IFIM modeling produces a variety of habitat suitability vs. discharge results. A systematic method for integrating hydrologic statistics for the reach under consideration, management objectives, and IFIM model results should be agreed upon between the agencies with management responsibilities for the river. A process such as described by Geer (1987) could be used to arrive at low flow recommendations.

Need for Coordinated Dam Operation During Low Flow Periods

7.5 Regulation of the main stem dams downstream of the headwaters lake and other dams in the basin must be carefully coordinated during drought periods to avoid artificially induced discharge fluctuations. Generally, dam operation during low flow periods should be targeted toward maintaining even river discharge over time, rather than closely regulating pool elevations behind the dams. Some large percentage decreases in river discharge from one day to the next resulted from main stem dam operation during the 1988 drought, at a time when natural river discharge was undergoing a very gradual recession (Appendix C). We recommend that main stem dam operators, key water users, the MDNR, and the Federal Energy Regulatory Commission carefully coordinate river regulation during future drought events. An even recession in flow, without large daily fluctuations in discharge, would greatly reduce the adverse effects of low flows on aquatic life in the river.

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APPENDIX F

TREATY TRUST CONSIDERATIONS

TREATY TRUST CONSIDERATIONS

The following is the conclusions section of a memorandum for Colonel Roger L. Baldwin from Edwin C. Bankston, District Counsel, dated 5 July 1989. The previous sections of the memorandum describe the case history and basis for these conclusions.

Following the conclusions section is a memorandum for record of a meeting between the District Engineer and District Counsel to discuss conclusions. the memcrandum for record contains valuable rationale for consideration of the Treaty Trust responsibility prior to any emergency supplemental low flow discharges from the headwaters lakes project. However, the discussion is not intended to explore the entire extent of American Indian rights. Thus, the discussion for uses on the rights that are pertinent only the Headwaters Lakes project.

The Chippewa Indians possess federally protected aboriginal and treaty rights to waters that are necessary to fulfill the purpose of the reservations. Wild rice is also culturally significant to the Chippewa people. Wild rice has a deep seated cultural, religious and health significance to Chippewa life. Such rights include, but are not necessarily limited to that quantity of water needed for the production and harvesting of Tribal Trust resources, such as wild rice. For example, production and harvesting of wild rice is water dependent and, under the Winter's doctrine, the Indians are entitled to waters necessary to produce and harvest a quantity of wild rice that is sufficient to meet their needs at a moderate living standard. However, it is very difficult to quantify that the amount of water needed to sustain a moderate living standard or Tribal Trust resources. Their rights to such waters are paramount and are superior to any other rights, other than those of the United States, which may be asserted, in this case navigation.

The United States and its agencies, including the Corps of Engineers, are fiduciary duty to the Indian Tribes to ensure that the Indian treaty rights are protected and are honored. To fulfill such duty, with respect to the

Chippewa's need for water in order to produce and harvest Tribal Trust resources the Government must, to the extent possible, ensure sufficient quantities of water to permit the production of sufficient quantities of routinely harvestable Trust resources which the Indians would desire to or could physically harvest.

The District Engineer, within limits prescribed by regulation, has the authority to operate the Mississippi River headwaters lakes in a manner that will result "in the greatest general benefit or the minimum of injuries to all affected interests." At a minimum, absent very unusual and compelling circumstances, it would not be "in the greatest general benefit or the minimum of injuries to all affected interests" to dishonor the Government's fiduciary duties to the Indians and to augment the routine low flow releases with water needed for the production and gathering of Tribal Trust resources. Therefore, absent a determination that augmentation of the routine low flow releases would not adversely affect the Indians' ability to gather all the Trust resources they should desire to gather routine low flow releases should not be augmented from Treaty Trust affected lakes (Leech, Winnibigoshish, Sandy). Further, even should it be determined by the District Engineer that emergency low flow releases will not adversely affect the ability to gather Tribal Trust resources, agreement of the Tribal Governments should be sought. Conditions that threaten human health and safety may be a justification to accept, on a one-time basis, damaging effects on Tribal trust resources from limited amounts of emergency low flow releases. Note: The same rationale and conclusions would pertain to all water dependent protected rights the Tribe may have, such as fish, game or wild rice harvest rights.

CENCS-PD-PF

31 August 1989
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MEMORANDUM FOR THE RECORD

SUBJECT: Headwaters Low Flow Review; Meeting on Indian Treaty Rights and Opinion Paper by District Counsel

1. On 14 August 1989, the District Engineer and District Counsel (OC) met with Headwaters Low Flow team members and some of their supervisors. The objective was to review the OC memorandum for Colonel Baldwin, dated 7 July 1989, same subject as above. The OC memorandum seems to focus on wild rice as the example of Trust resources, but future decision-makers from the District must remember that fish, game and any other water related resource are also subject to the following rationale. In fact, the fishery probably provides the greatest economic benefit to the Bands of any of the project related Trust resources.

2. Colonel Baldwin determined that an indemnification statement from the State of Minnesota would not be required. Further, Tribal representatives have indicated that such an indemnification is not desirable to them.

3. The Corps of Engineers policy of a water supply contract in response to Section 6 of the Flood Control Act of 1944 may not be required for the emergency releases from the Headwaters Lakes. However, the draft report should mention it as a possibility and that OC is seeking clarification from higher authority. There is also concern by the Bands that charging for water may be perceived as a buyout of Tribal rights which is contrary to Tribal desires and is seen by them as a potential validation of future use of water needed for Trust resources to meet growing needs in the Twin Cities.

4. To clarify the priority for use of surplus project waters, paragraph 2b.(d) (4) of the opinion paper indicates that surplus waters are those project waters that are not required first for navigation. Above specific lake stages, the District Engineer will determine what project waters are not required for navigation and will also determine how the surplus waters will be used in the greatest general benefit or minimum injuries to all affected interests. Other than the Congressionally authorized navigation purpose, the next priority for surplus waters is to meet Congressionally reserved (treaty) Tribal Trust resources for a moderate living standard, but not necessarily the maximum Trust Resources production. The third priority is for all the other recognized purposes. Assuming that navigation and Trust purposes are first satisfied, the use and trade-off of surplus waters for all the other recognized purposes is to be done according to normal federal economic and environmental principles and guidelines.

5. A question arose whether mechanized harvesting methods might be employed by the Indians to help overcome reduced access to wild rice beds during an emergency release. Consideration must first be given that the availability of mechanical harvesting may only serve to increase the desire to harvest and thus may not provide a means to satisfy the Trust responsibility when emergency releases are proposed. OC is researching who has the authority to permit nontraditional wild rice harvesting methods on Reservation lakes. Also to

consider is that the Indians might not choose to vary from the traditional methods, even if it were available to them. Thus, the consent of the Bands would be required for such a proposal. It is interesting to note that the Bands have used machinery in paddy production of wild rice.

6. Much discussion took place concerning the rationale for determining whether the Reservation Trust responsibility is satisfied. When a determination is needed, the first step is to consult the Tribes as to their expectations concerning their harvest of Trust resources that year. The Trust responsibility is based on the concept that the reservation resources are to provide for moderate living standards. However, moderate living standards (about $20,000 per family in 1986) would likely not be satisfied by complete harvest of all available fish, game, wild rice and other harvestables, at current market prices. Thus, the lessor of: (1) need, based on the moderate living standard, (2) desire or (3) capability to harvest should be met. Considerations include: prevailing natural production of each resource that year; higher prevailing market prices tend to increase the desire to harvest; lower project lake levels can reduce access to wild rice beds and stress production of all water related trust resources, but particularly fish and game. Lower lake levels can also make wild rice more vulnerable to storm damage and more difficult to harvest more than once.

7. A number of decision-making rationale were discussed:

a. The first step in responding to a request for supplemental low flows from the Headwaters project is to verify that an emergency exists that threatens human health and safety, such as a projected or actual human water supply shortage. In other words, the District Engineer would determine whether the emergency water needs are the highest and best use of the surplus waters, compared to navigation and the Trust responsibility. Based on available information, human health and safety low flow emergencies are expected to be a very unusual situations on the Mississippi River. However, the following rationale are provided in the unlikely event of such an emergency. Another consideration is that long range water supply planning efforts by the state, Metropolitan Council and local officials should make such emergencies even less likely to happen.

b. If the Tribal Trust can not be satisfied while making emergency releases from reservation lakes, then non-reservation lakes would be considered first. This decision might be contrary to minimizing economic losses. Under such conditions, the primary objective would be to conserve the Tribal Trust resources and secondarily to minimize overall economic damages.

c. However, if the Tribal Trust responsibility can be satisfied, the larger reservation lakes (Winnibigoshish and Leech), typically have greater volumes of surplus water available for low flow releases. If the Tribal Trust responsibility would not be violated by emergency releases, then reservation lakes where that is true can be considered. The standard federal economic and environmental principles and guidelines would be used to decide how to releases surplus project waters from the 3 non-reservation lakes and those reservation lakes where the Trust would be met while making emergency releases.

d. Recoverability of reservation lake levels during the following water year is also considered for satisfying the Trust responsibility during the next year.

8. Colonel Baldwin determined that the working papers and report from this study will contain Indian Trust considerations, but the working papers will be approved by him before they are released to the other agencies. This will delay our proposed publication and review schedule by several weeks. The MDNR staff has indicated that the delay is acceptable to them.

Herbert A. Nelson

Herb Nelson
Study Manager
Plan Formulation Branch
Planning Division

APPENDIX G

SECTION 21 OF PUBLIC LAW 100-676 WATER RESOURCES DEVELOPMENT ACT OF 1988

CONTINGENCY PLAN FOR REGULATION OF HEADWATERS RESERVOIRS

A draft contingency plan has been developed to respond to Section 21 of the Water Resources Development Act (WRDA) of 1988 (Public Law 100-676). The contingency plan considers two distinctly different regulation situations: high water conditions when the project lake levels exceed the upper elevation limits specified in the law and low water conditions when project lake levels drop below the lower limits specified in the law. This appendix summarizes the low water requirement because of its relationship to the existing low flow plan. The high lake level contingency plan is not discussed here because it is outside the scope of this low flow review.

The thrust of the requirement is that Congress shall receive at least 14 days' notice of when project lake levels are expected to drop below specific elevations. The specified elevations are as follows:

Reservoir	Elevation
Winnibigoshish Lake	1296.94
Leech Lake	1293.20
Pokegama Lake	1270.42
Sandy Lake	1214.31
Pine River Dam	1227.32
Gull Lake	1192.75

The following exhibits 1 through 6 compare the lake level limits established by the WRDA 1988 to other recognized desirable lake elevation ranges.

LAKE WINNIBIGOSHISH REGULATION BANDS

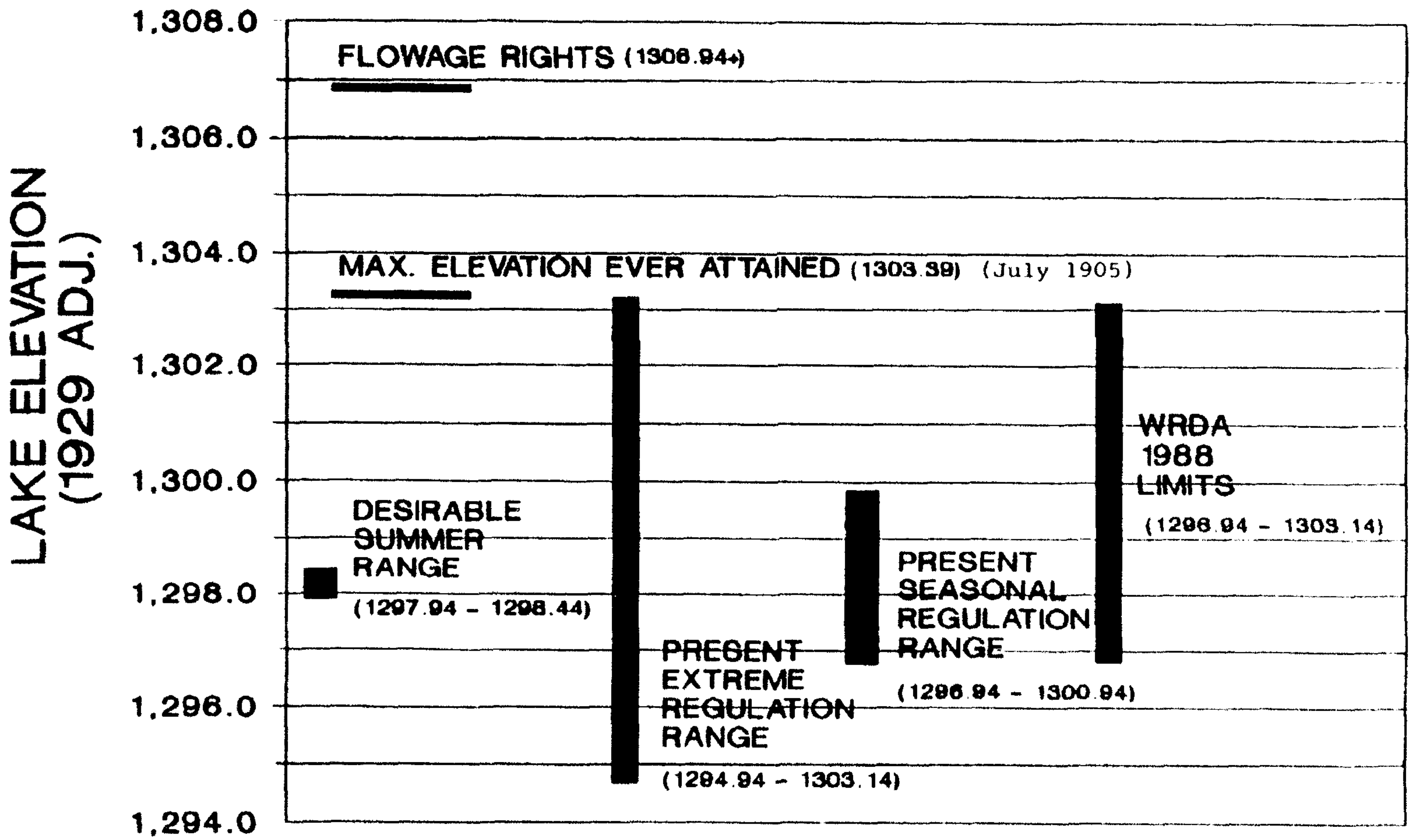

EXHIBIT 1

LEECH LAKE REGULATION BANDS

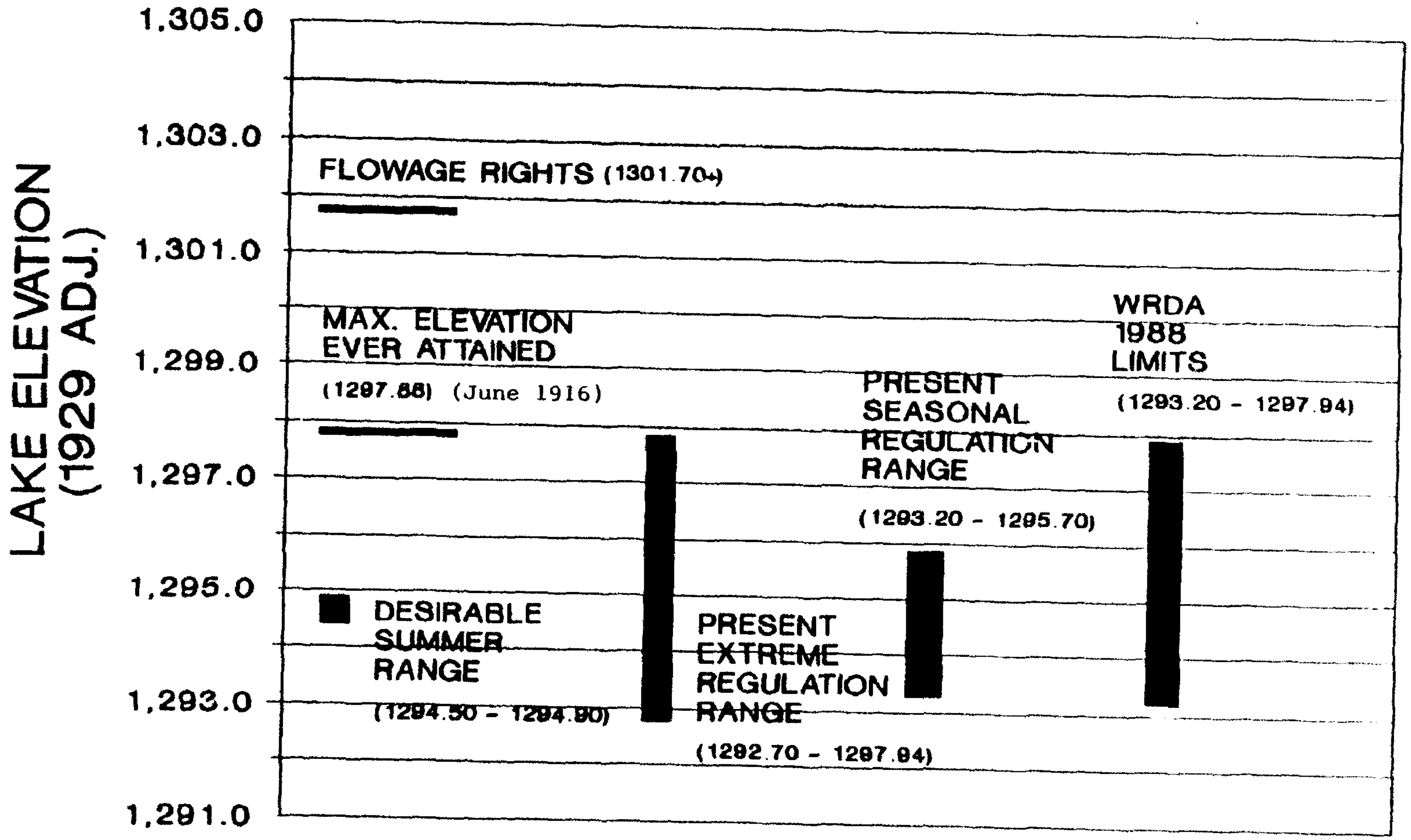

EXHIBIT 2

POKEGAMA LAKE REGULATION BANDS

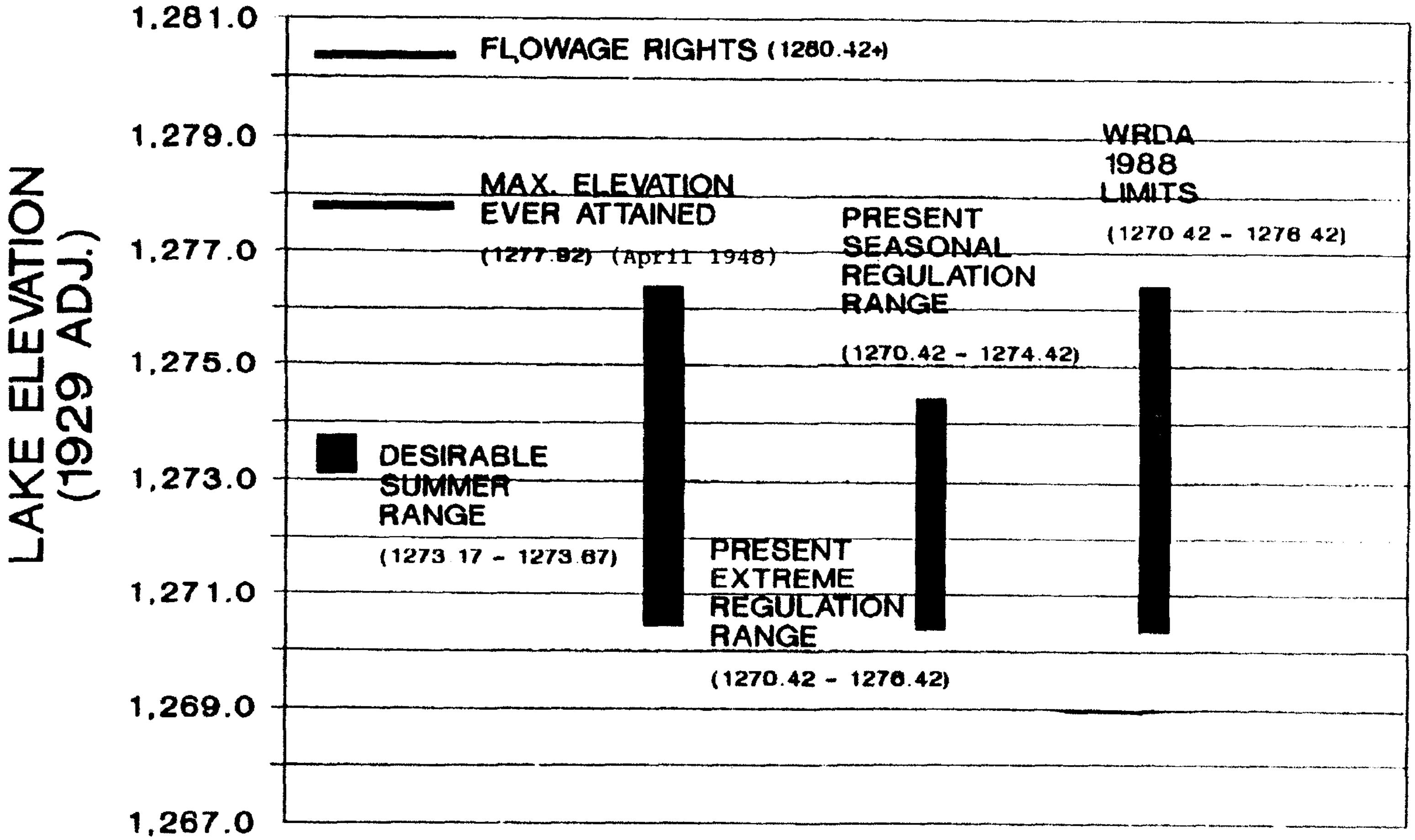

EXHIBIT 3

SANDY LAKE REGULATION BANDS

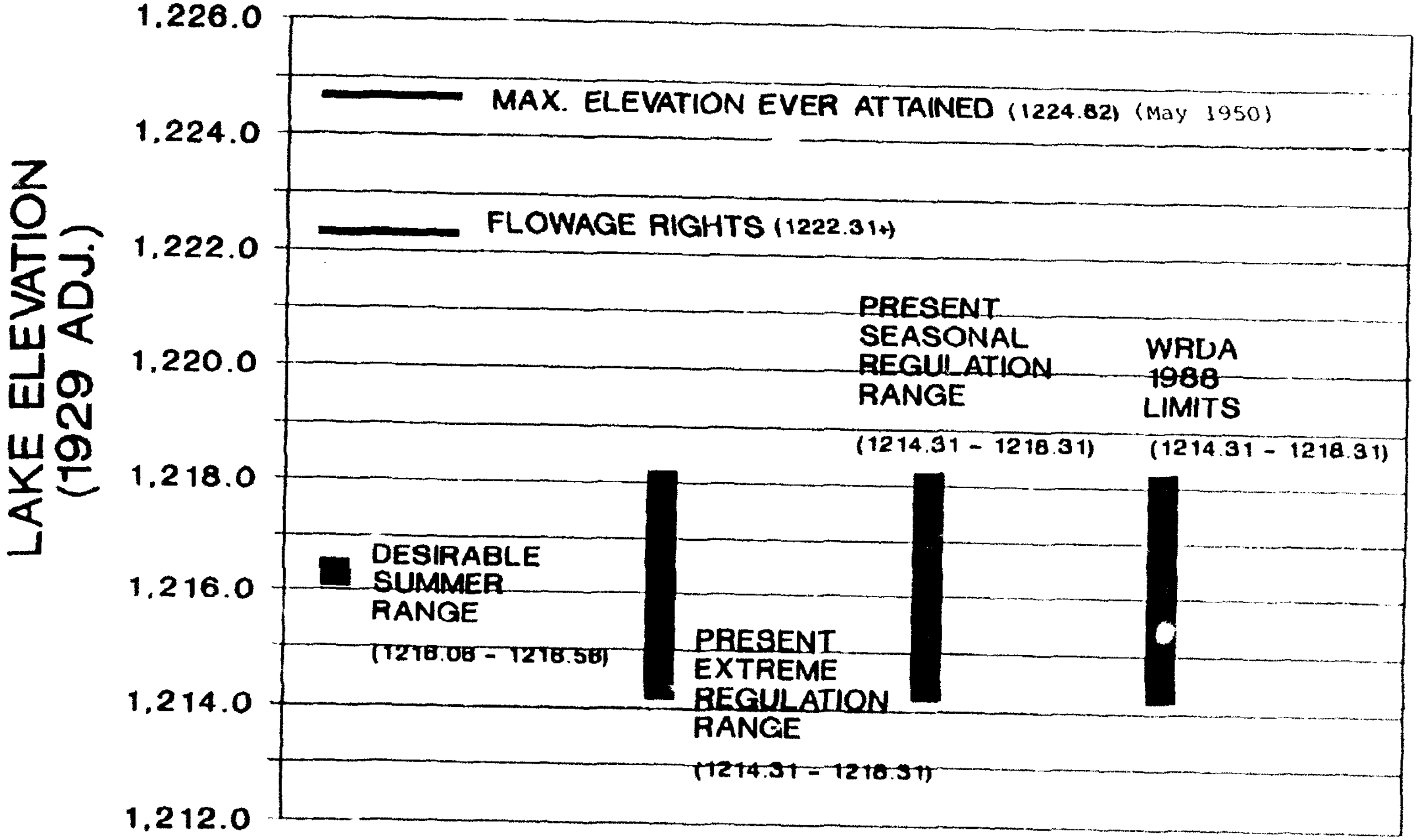

EXHIBIT 4

PINE RIVER
REGULATION BANDS

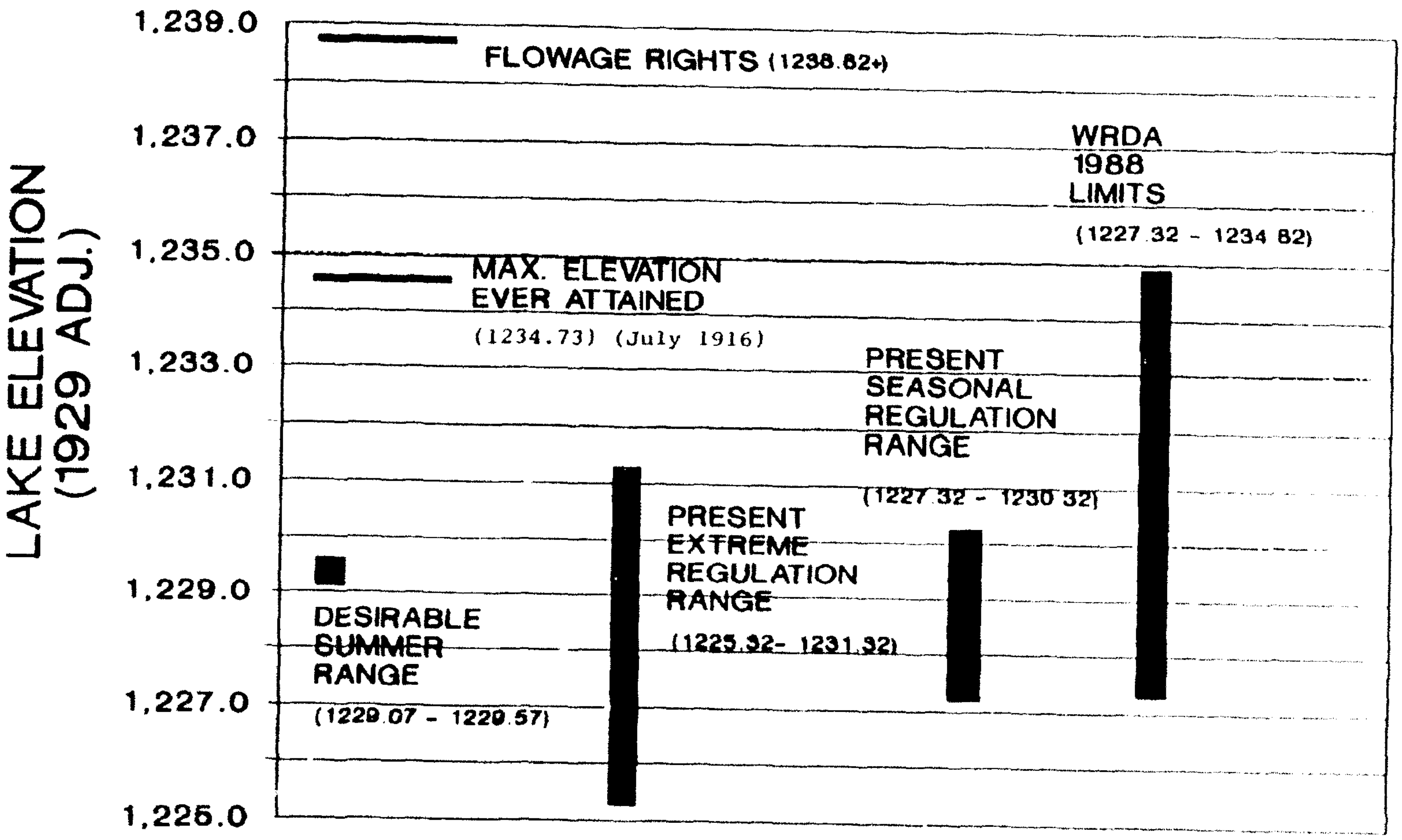

EXHIBIT 5

GULL LAKE REGULATION BANDS

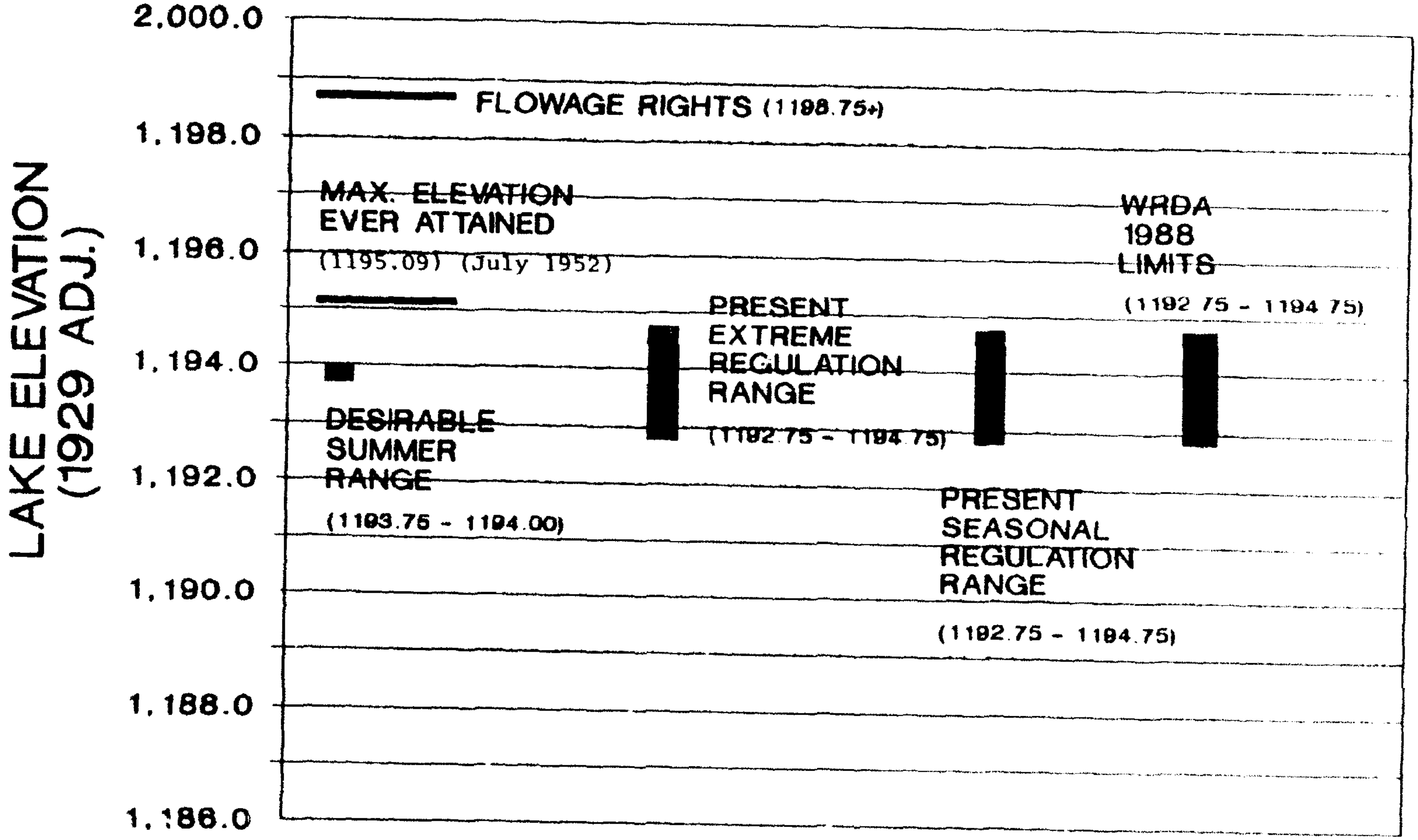

EXHIBIT 6

APPENDIX H

LOW FLOW FREQUENCY CHARACTERISTICS

LOW FLOW FREQUENCY CHARACTERISTICS

The following information was taken from the Water Resources Investigation Report 86-4353 by the U.S. Geological Survey, prepared in cooperation with the Minnesota Environmental Quality Board and the Minnesota State Planning Agency through the U.S. Army Corps of Engineers and the Minnesota Department of Natural Resources.

The USGS report supersedes a similar report by Lindskov (1977). With the addition of 8 years of record, low-flow frequency characteristics were updated for many of the continuous-record streamflow stations and new stations were added to the compilation.

The source of daily flow information for discontinued and current continuous-record streamflow stations was the Water-Data Storage and Retrieval System (WATSTORE; Hutchison, 1975), which is maintained by the U.S. Geological Survey. All availabl. streamflow records from 1892 through the 1983 water year were considered in the analyses.

Low flow is defined as the lowest average flow for some consecutive-day period. The 1-, 7-, and 30-day low-flow series were computed from the record of each station for each climatic and seasonal period. Frequency characteristics for the climatic and seasonal (May - September) data were determined using a Log-Pearson type III frequency distribution computer program available in WATSTORE. Frequency curves were prepared for the referenced report only for stations having 10 or more years of continuous record. Another method of defining frequency characteristics is preferable for the 53 stations with less than 10 years of record (Riggs, 1972). Results for the remaining 175 stations are presented in the referenced report.

EXPLANATION OF TERMS

Frequency and Recurrence Interval - are terms commonly used interchangeably in referring to extremes in streamflow. Frequency of flow is an average of the number of flows that will at least equal in severity a given value for a certain time period. Conversely, recurrence interval is the average time, in years, between such flows. The year a drought or flood of a given magnitude will occur cannot be predicted, but the probable number of such events during a reasonably long period of time may be estimated.

For example, a low-flow discharge of 3 ft^3/s having a recurrence interval of 5 years indicates that a discharge lower than 3 ft^3/s will occur as an annual minimum at intervals averaging 5 years. Phrases such as "10-year discharge" are commonly used in discussing extremes having the indicated recurrence interval, in years. Similar terminology is used in this report. For example, "7-day 10-year low flow" refers to the lowest mean discharge for 7 consecutive days having a recurrence interval of 10 years.

EFFECTS OF 1988 LOW FLOWS

The 1988 low flows generally caused the 7Q10 figures to drop significantly at most gages on the Mississippi River. The 7Q10 discharge is used an administrative decision trigger by state agencies. The actual discharge figure that is used for administrative purposes is computed from a statistical analysis of historic low flow event, however. The 7Q10 at the St. Paul gage was computed at 1250 cfs after the 1988 low flows.

Groundwater Effects on Low Flow Characteristics

There is a hydrologic connection between Mississippi River streamflows and adjacent aquifers. Water exchange can occur in both directions between the streamflow and the waters contained in adjacent aquifers. However, numerous factors affect the water exchange that can be quite complex to account for. Further, this hydrologic exchange is difficult to model because of the variability of the hydrogeology in the study area. Thus, only crude estimates are available at the time of this report, based on

gross evaluation of historic low flow data. The U.S. Geologic Survey (USGS) did a brief review of historic stream flow, as part of this low flow review. The tentative conclusion is that groundwater might contribute between 500 to 600 cfs during low flow events on the Mississippi River. Also, the groundwater contributions would tend to taper off slowly, over a relatively long period of time, probably measured in terms of months.

The following water fact sheet from the USGS describes an effort to further quantify the relation of ground-water flow in bedrock aquifers and Mississippi and Minnesota Rivers in the St. Paul and Minneapolis areas. Further information may be available from the Minnesota District Office of the USGS.

NOTE: These low flow discharge figures were computed without using the 1988 low flows. It is expected that when these low flows are recomputed sometime in the future, using 1988 low flows, most of these discharges will be computed to be lower values.

LOW FLOW FREQUENCY CHARACTERISTICS DATA
TAKEN FROM USGS WATER RESOURCES INVESTIGATIONS
REPORT 86-4353

	100 YR.	50 YR.	20 YR.	10 YR.	5 YR.	2 YR.
WINNIBIGOSHISH MISSISSIPPI RIVER						
1 DAY	31.2	37.1	46.9	56.6	69.3	94.5
7 DAY	36.0	41.6	50.9	60.1	72.2	97.4
30 DAY	44.7	50.0	59.0	68.0	80.4	109.0
GRAND RAPIDS MISSISSIPPI RIVER						
1 DAY	0.0	0.0	31.9	64.3	117.0	267.0
7 DAY	20.8	31.9	57.4	91.9	153.0	342.0
30 DAY	40.6	59.6	102.0	158.0	254.0	545.0
LIBBY (BELOW SANDY RIVER) MISSISSIPPI RIVER						
1 DAY	68.4	91.4	138.0	196.0	293.0	585.0
7 DAY	99.2	128.0	185.0	253.0	362.0	679.0
30 DAY	128.0	163.0	233.0	315.0	445.0	822.0
AITKIN MISSISSIPPI RIVER						
1 DAY	140.0	183.0	266.0	362.0	514.0	923.0
7 DAY	177.0	224.0	314.0	416.0	573.0	990.0
30 DAY	212.0	271.0	381.0	505.0	693.0	1180.0
ROYALTON MISSISSIPPI RIVER						
1 DAY	216.0	274.0	384.0	508.0	699.0	1200.0
7 DAY	309.0	389.0	536.0	700.0	944.0	1560.0
30 DAY	366.0	455.0	619.0	802.0	1070.0	1770.0
ELK RIVER MISSISSIPPI RIVER						
1 DAY	357.0	432.0	571.0	725.0	961.0	1600.0
7 DAY	415.0	509.0	682.0	874.0	1160.0	1920.0
30 DAY	470.0	574.0	765.0	977.0	1300.0	2130.0
ANOKA MISSISSIPPI RIVER						
1 DAY	506.0	608.0	791.0	990.0	1280.0	2030.0
7 DAY	552.0	683.0	923.0	1180.0	1570.0	2510.0
30 DAY	601.0	752.0	1030.0	1340.0	1790.0	2910.0
ST. PAUL MISSISSIPPI RIVER						
1 DAY	637.0	757.0	975.0	1210.0	1560.0	2460.0
7 DAY	768.0	907.0	1160.0	1430.0	1820.0	2810.0
30 DAY	884.0	1040.0	1310.0	1610.0	2040.0	3120.0
LEECH LAKE RIVER AT FEDERAL DAM						
1 DAY	29.8	35.6	45.3	54.6	66.2	87.1
7 DAY	38.5	43.7	52.0	60.0	70.3	91.1
30 DAY	46.8	51.3	58.8	66.1	76.1	98.3
SANDY RIVER AT SANDY LAKE DAM						
1 DAY	0.0	0.0	0.0	0.0	0.0	4.9
7 DAY	0.0	0.0	0.0	2.9	5.1	11.4
30 DAY	1.9	2.4	3.5	4.9	7.3	15.9
PINE RIVER AT CROSS LAKE DAM						
1 DAY	2.9	4.4	7.7	12.0	19.3	39.5
7 DAY	6.5	8.2	11.7	15.7	22.1	40.6
30 DAY	8.7	11.2	16.0	21.6	30.4	54.5
GULL RIVER AT GULL LAKE DAM						
1 DAY	2.2	3.0	4.5	6.4	9.1	15.8
7 DAY	2.9	3.9	5.7	7.8	10.7	17.3
30 DAY	4.0	4.9	6.6	8.4	11.3	19.3

WATER FACT SHEET

U.S. GEOLOGICAL SURVEY, DEPARTMENT OF THE INTERIOR

RELATION OF GROUND-WATER FLOW IN BEDROCK AQUIFERS AND MISSISSIPPI AND MINNESOTA RIVERS, ST. PAUL AND MINNEAPOLIS AREA, MINNESOTA

WHY STUDY GROUND-WATER FLOW TO THE MISSISSIPPI AND MINNESOTA RIVERS?

Ground water maintains the streamflow of the Mississippi and Minnesota Rivers in the Minneapolis-St. Paul area during periods of no rain or snowmelt. Seepage to these rivers from permeable sand and gravel aquifers supplies water to the rivers from their headwaters to the Minneapolis-St. Paul area. Seepage from four bedrock aquifers in the Twin Cities aquifer system augmented the mean January flow for the dry years of 1977 and 1988 by 820 and 680 cubic feet per second, respectively, in the Minneapolis-St. Paul area.

Wells that withdraw water from the bedrock aquifers beneath the Minneapolis-St. Paul area can intercept ground water that might otherwise flow to the Mississippi and Minnesota Rivers. The resultant reduced streamflow may lead to conflicts with other uses of surface water, such as public water supply, dilution of sewage effluent, and navigation. Possible distributions of increased ground-water withdrawals could induce the flow of water from the rivers into the aquifer system; leaching of contaminants from river-bottom sediments into the ground-water system could represent a potential hazard. An improved understanding of the hydraulic connection between the Mississippi and Minnesota Rivers and the bedrock aquifers will aid in evaluating the effects of ground-water withdrawals on streamflow and ground-water quality.

The U.S. Geological Survey, in cooperation with the Minnesota Department of Natural Resources and the Legislative Commission on Minnesota Resources, is investigating the hydraulic connection between aquifers and the Mississippi and Minnesota Rivers. This fact sheet briefly describes factors that control the seepage of ground water into the rivers and how these factors affect the availability of ground water to augment streamflow.

HOW IS THE HYDRAULIC CONNECTION BETWEEN BEDROCK AQUIFERS AND RIVERS STUDIED?

The hydraulic connection between the bedrock aquifers and the rivers is being studied intensely along three transects located across the Mississippi River north of Minneapolis, the Mississippi River in Minneapolis, and the Minnesota River about 5 miles upstream from its mouth (fig. 1). Ground-water flow is generally perpendicular to the rivers at all transects. In addition, each location, as discussed below, represents a different hydrogeologic relation between the bedrock aquifers and the adjacent river valley.

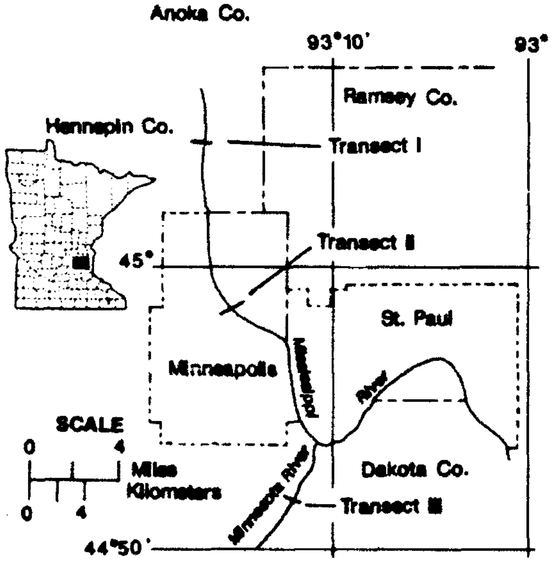

Figure 1.--Location of study area

All available hydrologic data were collected and evaluated along a reach of the river adjacent to each transect. Sources of data include water-well logs and soil borings for foundations compiled by the U.S. Geological Survey and the Minnesota Geological Survey; bridge and road test borings from the Minnesota Department of Transportation, river-dredging files of the U.S. Army Corps of Engineers; and other available geologic and geophysical maps, published reports, and engineering studies. Field data collected at each transect are summarized below.

Transect I extends across the Mississippi River where moderately thick alluvial and terrace deposits overlie glacial drift and shallow preglacial bedrock valleys (fig. 2). Test holes were drilled to 60 to 100 feet below land surface at 13 locations to determine stratigraphy in the river valley and to collect split-spoon samples for laboratory grain-size analysis and permeameter testing. Twenty-six piezometers and water-table wells, ranging in depth from 8 to 99 feet, were installed in seven clusters of wells on the eastern side of the river and one on the western side. The clusters are installed in a "T" pattern to help determine the three-dimensional distribution of the Prairie du Chien Group and St. Peter Sandstone of Ordivician age, glacial drift of Wisconsin Age, and Holocene alluvium. Water levels are measured in each well and in the river to determine changes in horizontal and vertical hydraulic gradients in response to natural and artificial stresses on the aquifer system. Additional information on geology was obtained from a low-frequency marine seismic-reflection survey and a surficial seismic-refraction survey. Ground-water samples were collected with a minipiezometer from under or adjacent to the Mississippi River, and from bedrock wells in surrounding areas.

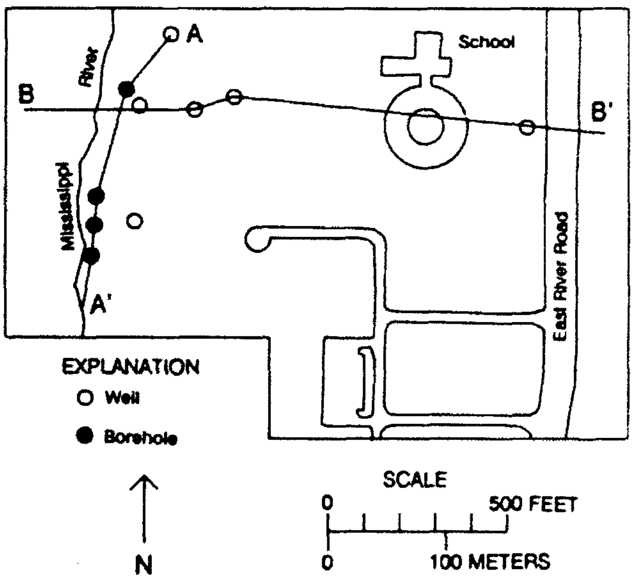

Figure 2.--Location of transect I

Transect II is located along the Mississippi River where thin alluvium overlies shallow bedrock. Along transect II, logs of deeper bedrock wells and borings for bridge foundations showed that shallow deposits (10 to 25 feet) of reworked sand from the underlying St. Peter aquifer fill the river valley. A low-frequency marine seismic-reflection survey confirmed information from bridge borings.

Transect III extends across the Minnesota River where thick alluvial deposits partly fill deep preglacial bedrock valleys and overlie complex drift deposits and the Prairie du Chien-Jordan aquifer (Prairie du Chien Group of Ordovician age and Jordan Sandstone of Cambrian age). Data from shallow water-table wells constructed at four locations in the Minnesota River valley completed the hydrogeologic picture provided by data from deeper bedrock wells located on the adjacent highlands, data from borings for bridge foundations in the valley, and data from available geologic maps. Water-quality samples were collected to determine geochemical signatures of different hydrogeologic units.

CLAY- AND SILT-RICH DEPOSITS COMPLICATE UNDERSTANDING OF HYDRAULIC CONNECTIONS

Clay- and silt-rich unconsolidated alluvial and glacial deposits retard the flow of ground water from the bedrock aquifers to the Mississippi and Minnesota Rivers more than do sandy deposits. The vertical hydraulic conductivity (the ability of a unit thickness of an aquifer to vertically transmit or retard flow) of the unconsolidated deposits in each river valley influences the timing of the effects of ground-water withdrawals from bedrock aquifers on ground-water flow to the rivers. If vertical hydraulic conductivity of the unconsolidated deposits is large compared to horizontal hydraulic conductivity of the bedrock aquifers, the effect of ground-water withdrawals on the flow of the river could be detected in a matter of days. Such an effect could lead to serious conflicts between users of ground and surface water. If the vertical hydraulic conductivity of the unconsolidated deposits is small relative to horizontal hydraulic conductivity of bedrock aquifers, the maximum effect of ground-water withdrawals on river flow could be delayed for weeks or months. In addition, a reduction in ground-water flow from bedrock aquifers to the rivers would continue until the water that was depleted from aquifer storage was replaced.

Estimating the delay time between peak ground-water withdrawals and their effects on the flow of ground water to the rivers is important. If the delay time coincides with a period of adequate overland run off (spring, early part of the summer, and fall), there can be an adequate supply of river water for municipal supply, dilution of sewage effluent, and in-stream uses. If, however, the delay time coincides with periods of reduced or no overland runoff (late part of the summer and winter), there can be an inadequate supply of river water for these uses and the quality of the water could become unacceptable for some uses.

Drilling at transect I helped identify the factors that control the hydraulic connection between the uppermost bedrock aquifers and the Mississippi River. Figure 3 shows the distribution of unconsolidated and bedrock aquifers. Increased upward ground-water flow could occur along the river where tills and glacial sand and gravels were removed and replaced by thick (50 feet) alluvial sands and gravels. Directions of ground-water flow shown on the West-East cross section by arrows were inferred from measured hydraulic heads.

Flow from bedrock aquifers to the Mississippi and Minnesota Rivers through unconsolidated deposits in the river valley depends on the amounts and specific locations of clay, silt, and sand in those deposits. At one location south of transe[illegible] flow to Mississippi River is enhanced where the present-day river valley cuts ac[illegible] buried valley that was formed during the time of glaciation and later filled with [illegible] This ancient valley was incised to bedrock through layers of glacial sand and lake silts and clays.

Along the eastern edge of the Mississippi River, heads in the bedrock aquifer are as much as 12 feet above the water table in the surficial sand aquifers. Within the buried valley, where a layer of silt and clay has been eroded, the head difference of 12 feet is evenly distributed between the bedrock and the water table. However, outside of the buried valley, where the layer of lake silts and clays is present, two-thirds of the head difference occurs across that layer. The hydraulic conductivity of glacial sands within and outside of the buried valley are roughly equal. By applying Darcy's law, ground-water flow from the bedrock to the Mississippi River (per unit length of the river) through the buried valley (where lake silts and clays are absent) is estimated to be about three times the flow through areas away from the buried valley (where the layer of lake silts and clays is present).

ADDITIONAL WORK IS NEEDED

Additional work is needed along transects I and III to (1) provide information about seasonal changes in aquifer and river chemistry, and (2) conduct aquifer test to sample large-scale hydraulic properties.

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Prepared by M.E. Schoenberg, Hydrologist, St. Paul, Minnesota.

Open-File Report 89-268

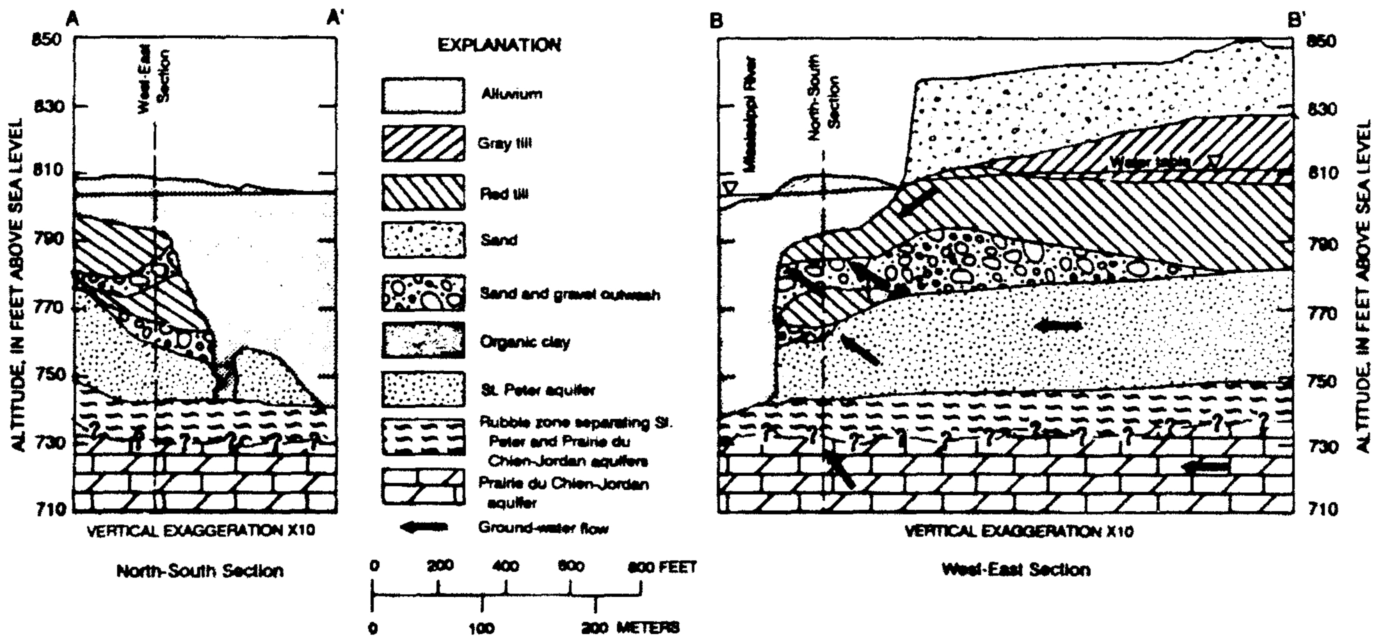

Figure 3.--Cross-sections at transect I.

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APPENDIX I

POWER GENERATION

TABLE OF CONTENTS

Water Requirements for NSP Minnesota Thermoelectric Generating Plants

David Herberling, Northern States Power, Minneapolis, MN

NSP's power plants are located on Minnesota's major river systems - the Mississippi, Minnesota and St. Croix Rivers (Figure 15), and water use characteristics of the plants are summarized in Table 8. the primary focus on water use and electrical generation during the 1988 drought was on NSP plants along the Mississippi River (Monticello and Sherco) upstream from the Twin Cities. These two power plants account for roughly half of NSP's base load generating system.

NSP thermoelectric power plants are as dependent upon cooling water as they are on fuel for generating electricity. Surface water use by NSP power plants is primarily for noncontact cooling purposes. Although these plants withdraw large quantities of water for cooling, their consumptive rates are low (see Table 8). Consumptive use rates are dictated by the type of cooing mode employed by the plant. An open-cycle plant, where water is pumped through the condenser and discharged directly back to the water source, consumes very little water. Plants that operate in either helper-cycle modes (where water is pumped through cooling towers prior to being discharged) or closed-cycle modes (where water is reused for cooling after being run through cooling towers. Except for Sherco, which operates closed-cycle year-round (Figure 16), NSP plants operate in helper or closed-cycle cooling modes only during the summer months.

Power plants can be operationally limited by both physical and regulatory cooling water constraints. From a physical standpoint, plants such as Monticello and Sherco, whose intakes are not in a regulated pool environment, are dependent upon river flow to provide adequate water elevation for pump intakes. For both Monticello and Sherco, the critical flow that provides the needed intake elevation is about 200 to 250 cfs. Other parameters that may affect plant generation by reducing condenser efficiency are water temperature and quality.

Note: There is also water requirements for thermal assimilation in the rivers. The requirements vary, depending on relative temperatures and flow rates combined to provide an adequate thermal sink for waste heat from electric generation.

Power plants also have regulatory constraints for both water appropriation and discharge. The Monticello plant is allowed to appropriate up to 645 cfs, but it cannot withdraw more than 75% of the river flow (Figure 17). When river flows drop below 860 cfs, the plant must begin to recirculate a portion of the cooling tower discharge water to the condenser. The plant has seasonal discharge temperature limits that can also restrict the amount of condenser cooling and, consequently, generation. The combined physical and regulatory water use constraints during the 1988 drought at times caused the Monticello plant to be limited to 70% of its generating capacity.

The generation loss at Monticello *up to 160 Mw -- enough electricity to serve 160,000 homes) occurred during a time of peak system demand. A major portion of this peak demand was air conditioning, with cooling degree requirements running 174% of normal during the 1988 summer months (Figure 18). The peak NSP system demand of 6930 Mw occurred on August 16, 1988. During this peak demand, power purchases constituted approximately 25% of the electrical service to NSP customers (Figure 19). It is estimated that replacement power purchases for each week that Monticello was limited to 75% power cost the average NSP residential customer an additional $0.07 to $0.09. Although the 1988 drought resulted in generating limitations for NSP facilities, service to NSP customers was never jeopardized because of a combination of system generation and power purchases. While the extent of the 1988 limitations to NSP generating facilities was tolerable, any condition, whether physical or regulatory, that would cause the loss of the entire generation capacity of both Monticello and Sherco under 1988 peak demand conditions would create power shortages for customers. They could also cause severe electrical equipment damage to the NSP system and the entire Mid-Continent Area Power Pool (MAPP).

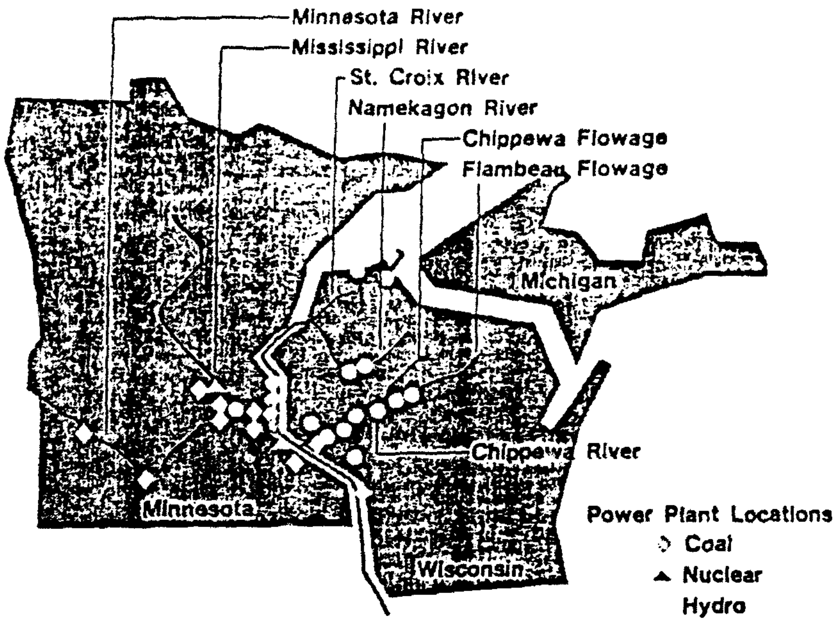


Figure 15. NSP Power Plant Location

Table 8. NSP Minnesota Thermoelectric Power Plant Surface Water Use Rates

Appropriation Plant	Generating Capacity (Mw)	Summer Cooling Mode	Maximum Consumpt. Use (cfs)	Permit Limit (cfs)
Miss. R. above TC				
Intakes				
Sherco (Becker)	2200	Closed	47	67[1]
Monticello	547	Helper	10	645
Miss. R. below TC				
Intakes				
Riverside (Mpls)	326	Open	1	543[2]
High Bridge (St. Paul)	360	Open	1	490[1]
Prairie Island (Red Wing)	1064	Closed	30	1360
Red Wing	24	Open	<1	84[1]
Minnesota River				
Minnesota Valley (Granite Falls)	47	Open	<1	118[1]
Wilmarth (Mankato)	20	Open	<1	51[1]
Black Dog (Burnsville)	443	Open	1	633[2]
St. Croix River				
King (Oak Park Heights)	571	Helper	14	660

[1] Converted from gpm limit
[2] Converted from acre-feet per year limit

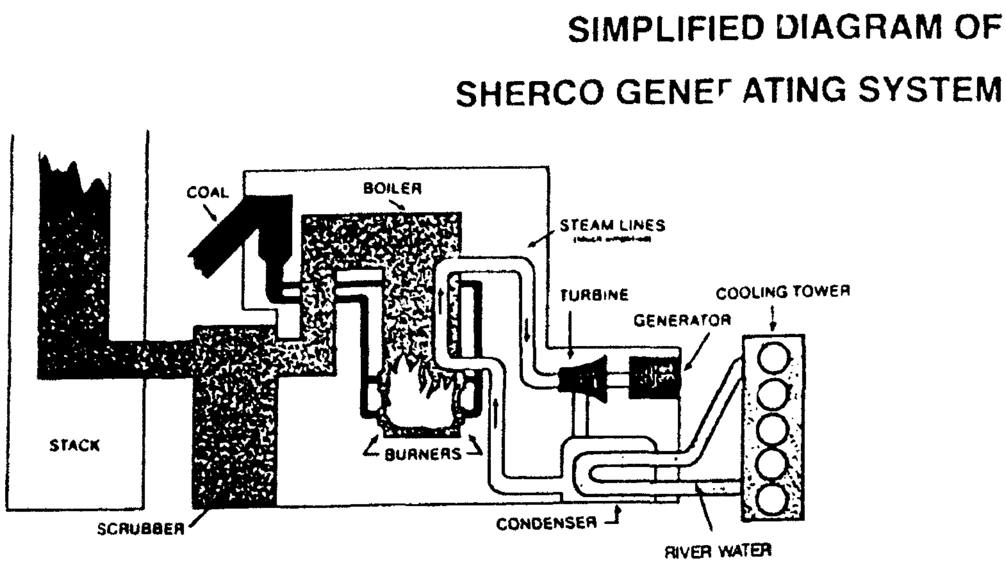


Figure 16. Sherco generating system

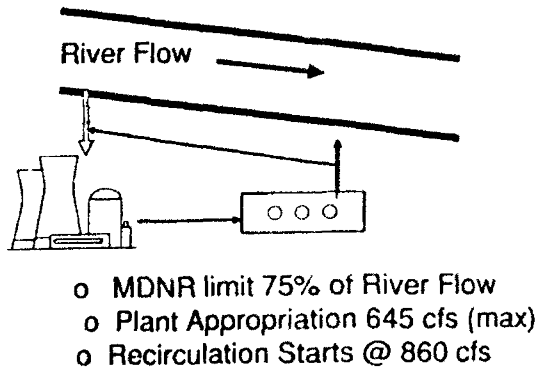


Figure 17. Appropriation limits

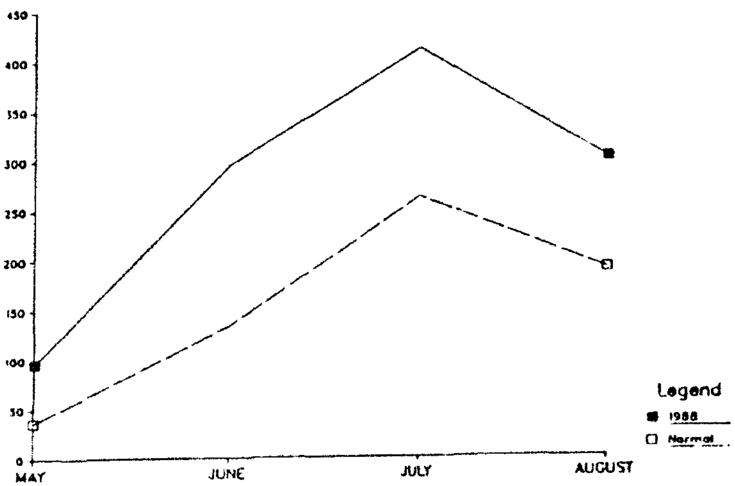


Figure 18. 1988 cooling degree days vs normal

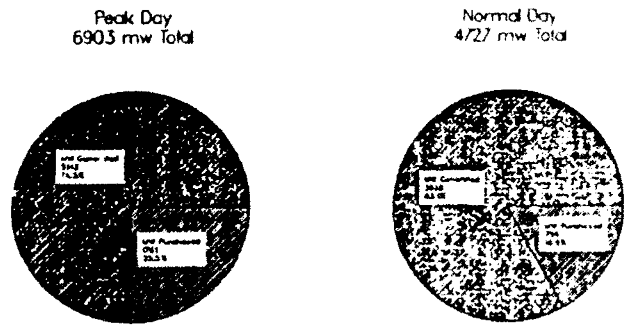


Figure 19. Meeting the demand

NSP

Northern States Power Company

414 Nicollet Mall
Minneapolis, Minnesota 55401
Telephone (612) 330-6007

Joseph A. Cascalenda
Vice President
Public Affairs

July 26, 1988

The Honorable Jim Oberstar
House of Representatives
2351 Rayburn Office Building
Washington, D.C. 20515-2308

Dear Congressman Oberstar:

Steve Thorne, MDNR Deputy Commissioner, informs us that you had questions in your July 14, 1988 congressional subcommittee hearing regarding the impact of low river flows on NSP generating facilities. We appreciate this opportunity to advise you about our situation.

At the present time, our generation system is in excellent shape. Through a combination of our own generation and power purchases, we have not experienced any problems supplying our customer needs, even at our new peak demand of 6,710 Mw which occurred July 15. The drought has created some minor operating problems for our plants. Through both physical and regulatory operating constraints, it has had a limited effect on the generating capabilities of some facilities. To date, our Monticello plant on the Mississippi River has been affected the most by low river flow conditions.

Monticello has been experiencing some derates (inability to produce full generating potential) over the past month that are attributable to a combination of low river flow and high river water temperatures. These derates have ranged up to 25 percent (136 Mw) of the plant's 545 Mw rated capacity. Typically, these derates have ranged on a daily basis from 2 to 7 percent (10-40 Mw).

Power purchases within the Mid-Continent Area Power Pool (MAPP) have been and will continue to be available to replace our plant derates, such as Monticello's. Replacement power purchases of this magnitude are handled routinely by our system operations people. These purchases, however, can only be secured at a price that is greater than our own cost to produce the power, and unfortunately will result in some minor additional charges to our customers. Attempting to forecast these increases is extremely difficult because of the many variables involved: the extent of the derate which is a function of air and river conditions; its duration; our own system demand; the spot market for purchasing replacement power, the status of regional demand, etc. As you can see, it's much like trying to forecast the weather itself.

Despite these complexities, our system operations, energy supply planning and rate departments have developed their best estimate of these potential impacts to our customers. Under a scenario that assumes Monticello is derated 25 percent for one week, we

estimate replacement power expenses would result in a $0.07 to $0.09 increase in our average residential customer's bill for each month that the plant is affected. Our average residential customer typically uses 650 Kw hours of electricity and pays $44.00 per month. Therefore, a $0.07 to $0.09 increase would add about two-tenths of one percent to the monthly bill. Based on plant performance over the past month's low flow conditions, this estimated impact appears appropriate.

Although we would prefer to have sufficient river flows that would enable us to operate Monticello at its maximum potential, we are confident that our generating and power purchasing capabilities will enable us to continue serving our customers with reliable and economical electrical power under both existing and projected Mississippi River conditions. With the predicted low flows, we will have to operate some facilities at less than full capacity, but we do not anticipate any shutdown requirements.

We have been working extensively with the Minnesota Department of Natural Resources Drought Action Task Force to keep the state informed of our situation. There has been good cooperation among the various interest groups on this task force as we all struggle in this difficult time to balance the needs of the state and protect its resources. Thank you for the opportunity to explain our situation. If you have additional questions, Tom Connelly, in Washington, D.C. at 484-0094, or other members of my staff will be happy to provide further information.

Sincerely,

Joseph A. Cascalenda

Joseph A. Cascalenda
Vice President
Public Affairs

cc: Commissioner Joseph Alexander, MDNR
Colonel Roger Baldwin, Corps Eng., St. Paul
Commissioner Anthony Perpich, MPUC

DISPOSITION FORM

Used in lieu of DA Form 2496

REFERENCE OR OFFICE SYMBOL	SUBJECT
CENCS-PD-ES	Requested Information on Operation of the Monticello Nuclear Power Plant

TO	FROM	DATE	CMT1
Asst Chief, CENCS-ED	Chief, CENCS-PD-ES	18 July 1988 RASTER/238	

1. The plant would be in a touch-and-go keep-operating-or-shut-down situation if river flow dropped to 240 cfs at which point NSP is required to go to full recirculation (recirc) of cooling water plus about 100 cfs of make-up water (drawn from the river to make up for evaporation and dilute salinity buildup and then released back into the river).

2. Before that point, the plant gets into a D-RATE situation, i.e., deficiencies from extra in-plant power uses for fans and pumps plus condensor efficiency problems from high river water temperatures eat into power production. Recently, for instance, they had a D-RATE as high as 70 megawatts (MW), 13 % of the total 545 MW capacity.

3. The effect of recirculation, however, depends strongly on river temperature, too. A week ago when we had some cooler weather, they were producing full power despite 10 % recirc because the river water temperature was down to 74-75° instead of 80° as has been the case sometimes this summer.

4. Typically, the plant uses about 600 cfs for cooling purposes and returns 98-99 % (1-2 % evaporates). NSP is allowed a maximum of 645 cfs until this withdrawal equals 75 % of the river flow, i.e., when total river flow drops below 860 cfs; at that point, recirc has to begin.

5. The table below shows forecasts of rates for replacement power if the Monticello plant is <u>completely</u> shut down. These estimates are based on projections of normal demand and availability, scheduled downtime of other plants, etc. For partial power losses, estimate replacement power costs by proportion, i.e., if Monticello power production was cut in half from 545 MW to 227.5 MW, use half the rates shown.

July 1988	$182,400/day
August 1988	$154,400/day
September 1988	$130,500/day
October 1988	$140,700/day
November 1988	$154,000/day
December 1988	$170,700/day

[1] Based on telecons to Jack Perry and Dave Heberling, NSP System Control Center, Minneapolis)

Robert L. Northrup

ROBERT L. NORTHRUP
Chief, CENCS-PD-ES

PF/Nelson

CENCS-PD-PF

30 March 1989

MEMORANDUM FOR RECORD

SUBJECT: Mississippi Headwaters Low Flow Review; Meeting with Mid-continent Area Power Pool (MAPP)

1. On 21 March 1989, I met with three staff members from MAPP: Dave Lingo, Dr. Neill Burnett, and Jay Franklin; representatives of three member utilities: Northern States Power (NSP), Iowa Power and Light, and Dairyland Power; and Kurt Gunnard from the U.S. Geological Survey.

2. The MAPP Environmental Committee recently formed a Water Policy Subcommittee. A draft copy of the scope of activities of the subcommittee is attached. The scope includes coordination and monitoring governmental response to low flow events that cause generation problems for their member utilities.

3. The Headwaters low flow coordination plan or any other similar low flow coordination effort should include this subcommittee as well as NSP representatives.

4. The subcommittee will be polling its members for their low flow water requirements. This information will be provided to all Corps offices within their region. They are concerned that many member utilities do not know what flows or pool levels are needed to keep their intakes safely covered.

5. The subcommittee intends to help each utility identify its nearest gage that the National Weather Service (NWS) uses for stage/flow predictions. Thus, each utility can use the NWS predictions to determine whether their intakes are expected to be covered and their consumptive needs might be met.

6. Dr. Burnett also asked whether the St. Paul District has a model of the Mississippi System like the water control system for the Missouri River hydropower reservoirs. We do not have a computerized system like that. Water Control has talked conceptually about such a computer model and may attempt to program resources for the work sometime in the future. For now, the MAPP members will likely use the NWS prediction system to monitor low flow outlooks on the Mississippi River.

Encl

Herb Nelson
Project Manager
Plan Formulation Branch
Planning Division

DRAFT

SCOPE OF ACTIVITIES
Water Policy Subcommittee
MAPP Environmental Committee

AUTHORITY: The Water Policy Subcommittee is organized as a functional group reporting to the MAPP Environmental Committee and shall continue as such until its function, organization or status is altered by the MAPP Environmental Committee as a whole.

SCOPE: To be responsive to the MAPP Environmental Committee for all matters relating to the management, allocation, use, availability and quality of water systems in the MAPP region upon which member utilities must depend for continuous, reliable operation and supply of electrical energy.

ORGANIZATION: Membership shall be made up of five members, representative insofar as possible, of one member from each MAPP member utility located in the upper and lower Missouri and Mississipi River regions encompassed in the MAPP region and one member at-large. At least one of these five shall be a member of the MAPP Environmental Committee.

FUNCTIONS: The Water Policy Subcommittee shall be concerned with the following activities:

- o MAPP members require reliable, long-term, dependable, cost-effective supplies of surface and ground water. The Subcommittee will monitor state, regional and federal legislative and regulatory ~~trends~~ issues to identify and alert member utilities of any actions which will threaten water supplies.

- o Monitor water allocation information so that member utilities may be informed concerning water allocation legislation, rule making, planning and administration.

- o Be concerned with both surface and ground water supplies and quality.

- o Where appropriate, encourage more efficient water use and water management.

- Be proactive in the search for and identification of water policy issues and emerging problem areas to include the Water Concerns list, and the MAPP Water Policy statement.

- Keep abreast of scientific and technical trends in water management and utility use and ensure that member utilities are well informed.

- Monitor governmental response to drought or chronic water shortage situations to ensure that all water users are treated fairly and equally according to their water uses and needs, and that utilities not bear a disproportionate share of any shortage.

- Maintain an effective information and communication channel between the activities of the Subcommittee, other MAPP Committees and member utilities, with the consent of the Environmental Committee.

- Prepare issue identification papers, alert notification, surveys and studies as required, in response to need, and Environmental Committee requirements in order to better serve the functions of the Subcommittee.

- Prepare annual budget requirements for Environmental Committee consideration.

- Plan, prepare and conduct symposiums as required.

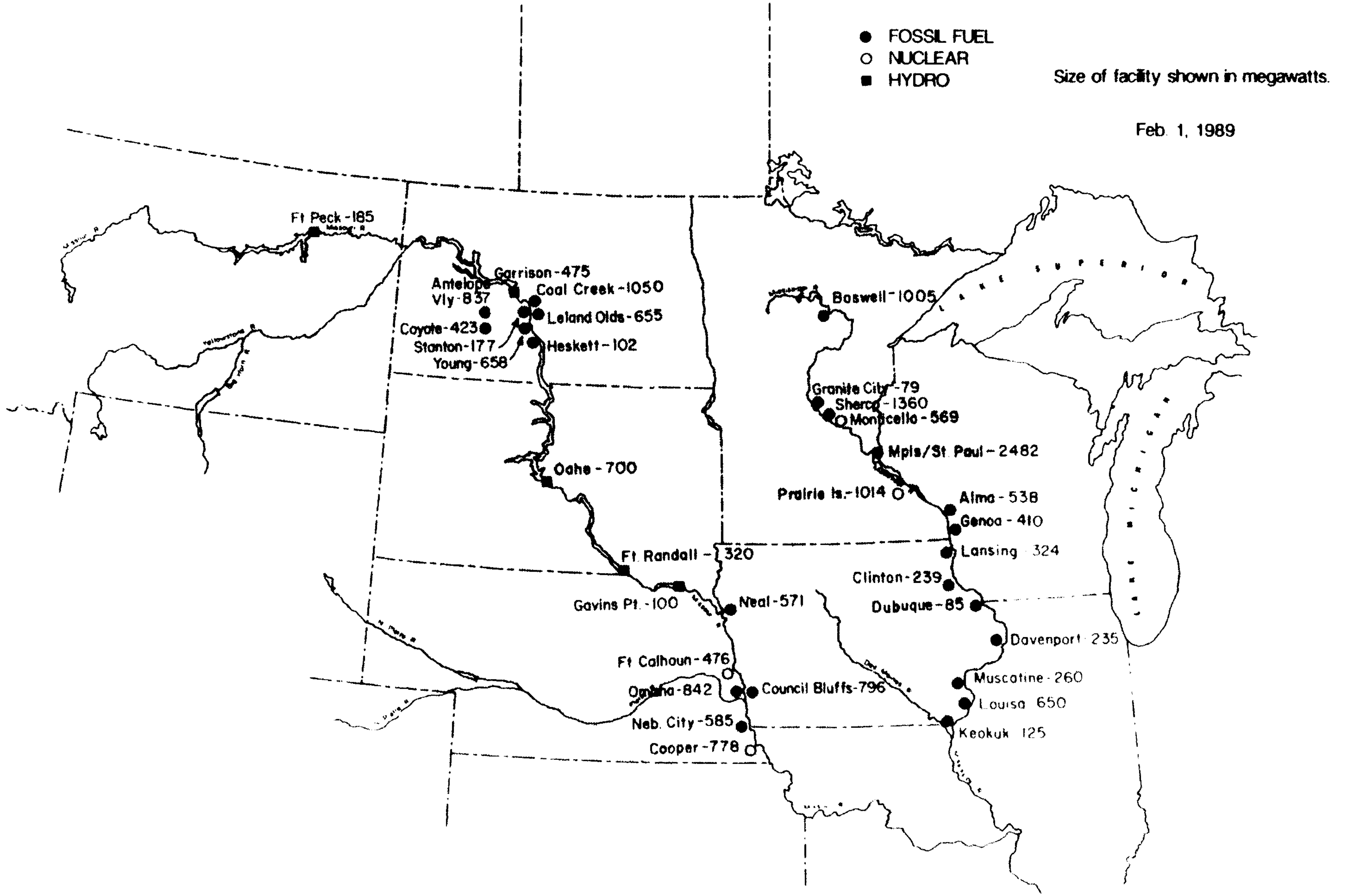
- Perform any other task assigned by the Environmental Committee.

MAPP ENVIRONMENTAL COMMITTEE

SYSTEM I.D.	SYSTEM NAME	ADDRESS	REPRESENTATIVE	ALTERNATE
CPA	Cooperative Power	14615 Lone Oak Rd. Eden Prairie, MN 55344	Will Kaul 612-937-8599	
DPC	Dairyland Power Cooperative	2615 E. Av. So. LaCrosse, WI 54601	Thomas Steele 608-788-4000	
IELP	Iowa Electric Light & Power Company	Box 351 Cedar Rapids, IA 52406	Pat McPartland 319-398-4180	
IIGE	Iowa Illinois Gas & Electric Company	206 E. 2nd St. Davenport, IA 52808	K.T. Albertson (Vice-Chairman) 319-326-7114	
IPS	Iowa Public Service Company	Box 778 Sioux City, IA 51102	Dave Dooley 712-277-7509	Tim Rollinger 712-277-7616
MP	Minnesota Power	30 W. Superior St. Duluth, MN 55802	E.R. Kilpatrick 218-723-3931	Bob Lindholm 218-722-2641
MDU	Montana-Dakota Utilities Co.	400 N. 4th St. Bismarck, ND 58501	Neill C. Burnett 701-222-7990	
NPPD	Nebraska Public Power District	Box 499 Columbus, NE 68601	L. John Cooper 402-563-5333	
NSP	Northern States Power Company	414 Nicollet Mall Minneapolis, MN 55401	Joseph Wolf 612-330-5536	Robert Evans 612-330-6906
NWPS	Northwestern Public Service Company	3rd and Dakota So. Huron, SD 57350	Richard Green 605-352-8411	
OPPD	Omaha Public Power District	1623 Harney St. Omaha, NE 68102	William L. Neal 402-536-4576	
OTP	Otter Tail Power Company	215 So. Cascade Fergus Falls, MN 56537	Richard Steidl 218-739-8538 Engineering Committee Liaison	
UPA	United Power Association	Elk River, MN 55330	Dan McConnon (Chairman) 612-441-3121	Jim Eggen 612-441-3121
WAPA	Western Area Power Admin.	P.O. Box 3402 Golden, CO 80401	Warren Jamison 303-231-7945	
MAPP	Mid-Continent Area Power Pool	1111 3rd Ave. So. Suite 430 Mpls, MN 55404	David P. Lingo (Secretary) 612-341-4618	

Rev.03/88

MAJOR ELECTRIC GENERATION FACILITIES ON THE MISSISSIPPI AND MISSOURI RIVERS WITHIN THE MAPP REGION



430 Century Plaza
1111 Third Avenue South
Minneapolis, MN 55404
612-341-4600

mapp
mid-continent area power pool

March 31, 1989

Mr. Herb Nelson
St. Paul District Corps of Engineers
1421 U.S. Post Office
St. Paul, MN 55101-1479

Dear Mr. Nelson:

On behalf of the Water Policy Group of the MAPP Environmental Committee and myself, thank you for sharing your time and knowledge at our meeting last Tuesday. This whole drought issue seems very difficult to get our arms around, and it was good to have this information exchange.

Should you have reports or bulletins from time-to-time which you feel may be of interest to the MAPP region utilities, please send me a copy and I'll make sure it gets into the right hands.

Thank you again for your participation.

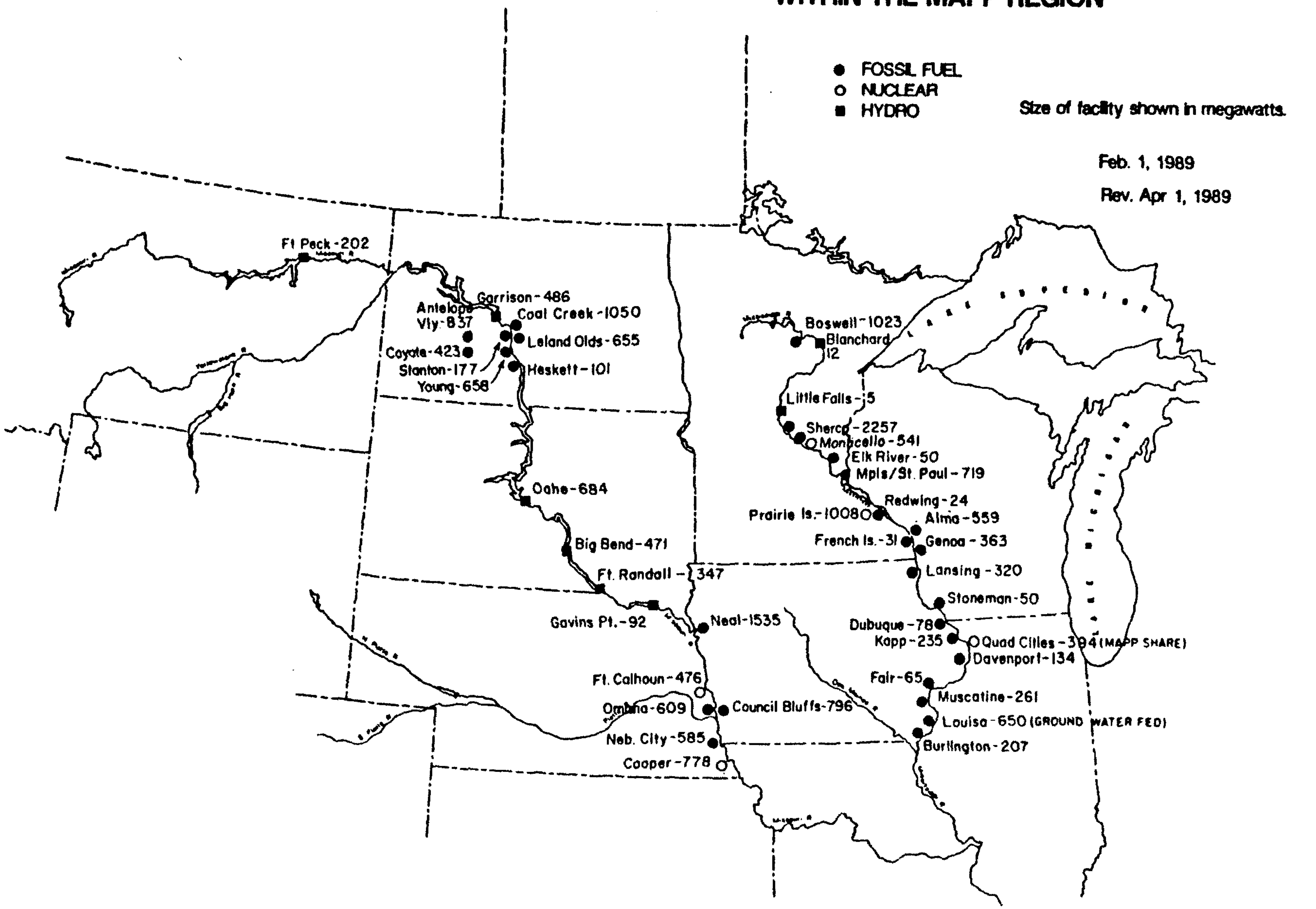
Sincerely,

Jay T. Franklin
Environmental Consultant

/jba

encl.

MAJOR ELECTRIC GENERATION FACILITIES ON THE MISSISSIPPI AND MISSOURI RIVERS WITHIN THE MAPP REGION



430 Century Plaza
1111 Third Avenue South
Minneapolis, MN 55404
612 341-4600

mapp

October 3, 1989

Dr. ~~Neal~~ Neill Burnett
Montana-Dakota Utilities
400 North Fourth Street
Bismarck, North Dakota 58501

Dear Dr. Burnett:

RE: Intake Structure Survey

Enclosed is data from the Intake Structure Survey. It includes all facilities of 50 megawatts or more that depend on Mississippi or Missouri River water. I tabulated the data from the most northern plant and worked downstream.

Two major facilities were not included in this data. Antelope near the Missouri River depends on a lake for its' intake requirements and Louisa near the Mississippi is ground water fed.

I will maintain the survey master and supporting documents at the MAPP office.

Sincerely,

Jay T. Franklin
Environmental Administrator

JTF/DLK

Enclosure (2)

cc: Dave Lingo-Mapp
Thomas A. Steele-DPC
Robin Fortney-IPS
Lee W. Eberley-NSP
John Cooper-NPPD
Mark Meyer-WAPA

MAJOR ELECTRIC GENERATION FACILITIES AFFECTED BY THE MISSOURI RIVER WITHIN THE MAPP REGION

UTILITY- FACILITY	LOCATION	MINIMUM WATER ELAVATION (MSG)
Cooperative Power Coal Creek	103,186 N 1,830,365 E	1652.0'
Montana-Dakota Utilities Coyote	River Mile 1,372.42	1657.43'
United Power Association Stanton	River Mile 1,372.0	1659.0'
Basin Electric Power Cooperative Leland Olds	River Mile 1,371.6	1651.5'
Minnkota Power Cooperative Young	River Mile 1,364.4	1653.0'
Montana-Dakota Util.Co. Haskett	46° 52' 1" LAT 100° 53' 1" LONG	1620.3'
Iowa Public Service Co. Neal 4	River Mile 717.0	1046.0'
Iowa Public Service Co. Neal 1-3	River Mile 719.0	1052.0'
Omaha Public Power District Fort Calhoun	River Mile 646.0	984.0'
Omaha Public Power District North Omaha	River Mile 625.0	965.0'
Iowa Power & Light Company Council Bluffs	River Mile 606.0	948.0'
Omaha Public Power District Nebraska City	River Mile 556.0	896.0'
Nebraska Public Power District Cooper	River Mile 532.5	870.0'

MAJOR ELECTRIC GENERATION FACILITIES AFFECTED BY THE MISSISSIPPI RIVER WITHIN THE MAPP REGION

UTILITY-FACILITY	LOCATION		MINIMUM WATER ELEVATION (MSL)
MN Power Clay Boswell	47° 52' 0" 93° 39' 16"	LAT LONG	1268.5'
Northern States Power Sherco	River Mile	904.5	913.5'
Northern States Power Monticello	River Mile	901.0	903.5'
United Power Assoc. Elk River	River Mile,	884.4	849.0'
Northern States Power Riverside	River Mile	857.0	796.33'
Northern States Power High Bridge	River Mile	840.8	686.0'
Northern States Power Prairie Island	River Mile	798.0	670.0'
Northern States Power Red Wing	River Mile	791.0	661.0'
Dairyland Power Cooperative Alma	River Mile	751.4-751.6	655.0'
Dairyland Power Cooperative Genoa	River Mile	678.4	615.0'
Interstate Power Company Lansing	River Mile	660.0	613.3'
Dairyland Power Cooperative Stoneman	River Mile	606.2	590.0'
Interstate Power Company Dubuque	River Mile	580.0	588.4'
Interstate Power Company Kapp	River Mile	514.0	565.0'
Commonwealth Edison Co. (IIGE) Quad Cities	River Mile	506.4	557.0'
Iowa-Illinois Gas & Electric Riverside	River Mile	490.0	555.49'
Central Iowa Power Cooperative Fair Station	River Mile	468.0	540.0'
Muscatine Power & Water Muscatine	River Mile	452.9	527.5'
Iowa Southern Utilities Burlington	River Mile	399.4	514.0'

APPENDIX J

WATER QUALITY AND WASTE ASSIMILATION

EVALUATION OF FLOW AUGMENTATION FOR POTENTIALLY IMPROVING WATER QUALITY IN THE MISSISSIPPI RIVER NAVIGATION POOL #2 DURING EXTREME LOW-FLOW CONDITIONS

BY

DENNIS D. HOLME
U.S. Army Corps of Engineers
St. Paul District, St. Paul, Mn

JOHN W. BARKO
WILLIAM F. JAMES
U.S. Army Engineers Waterways
Experiment Station, Vicksburg, Ms

Preliminary Evaluation Of Flow Augmentation For Potentially Improving Water Quality In The Mississippi River Navigation Pool #2 During Extreme Low-Flow Conditions

INTRODUCTION

During the summer drought of 1988 dissolved oxygen concentrations in the reach of the Mississippi River located between Lock & Dams 1 and 2 began to drop frequently below the 5 mg/l level considered critical for supporting aquatic animal life. There appeared to be a great potential for a major fish kill. The water quality of Pool 2 is affected by discharge from the Twin Cities metropolitan wastewater treatment plant and from other metro area treatment plants via the Minnesota River. The dissolved oxygen deficiency was attributable to Mississippi and Minnesota River flows falling below those for which the treatment systems were designed. Beginning in early June, as a water supply crisis appeared to be imminent, the Minnesota Governor's Drought Task Force began to develop a plan for implementing emergency water conservation measures and flow augmentation from the six Mississippi River headwaters reservoirs operated by the Corps of Engineers. Among the perceived benefits of flow augmentation was improvement of water quality conditions in Pool 2. The proposed measure was opposed by an association of people living in the Mississippi River headwaters lakes region and by

MISSISSIPPI RIVER TWIN CITIES METROPOLITAN REACH

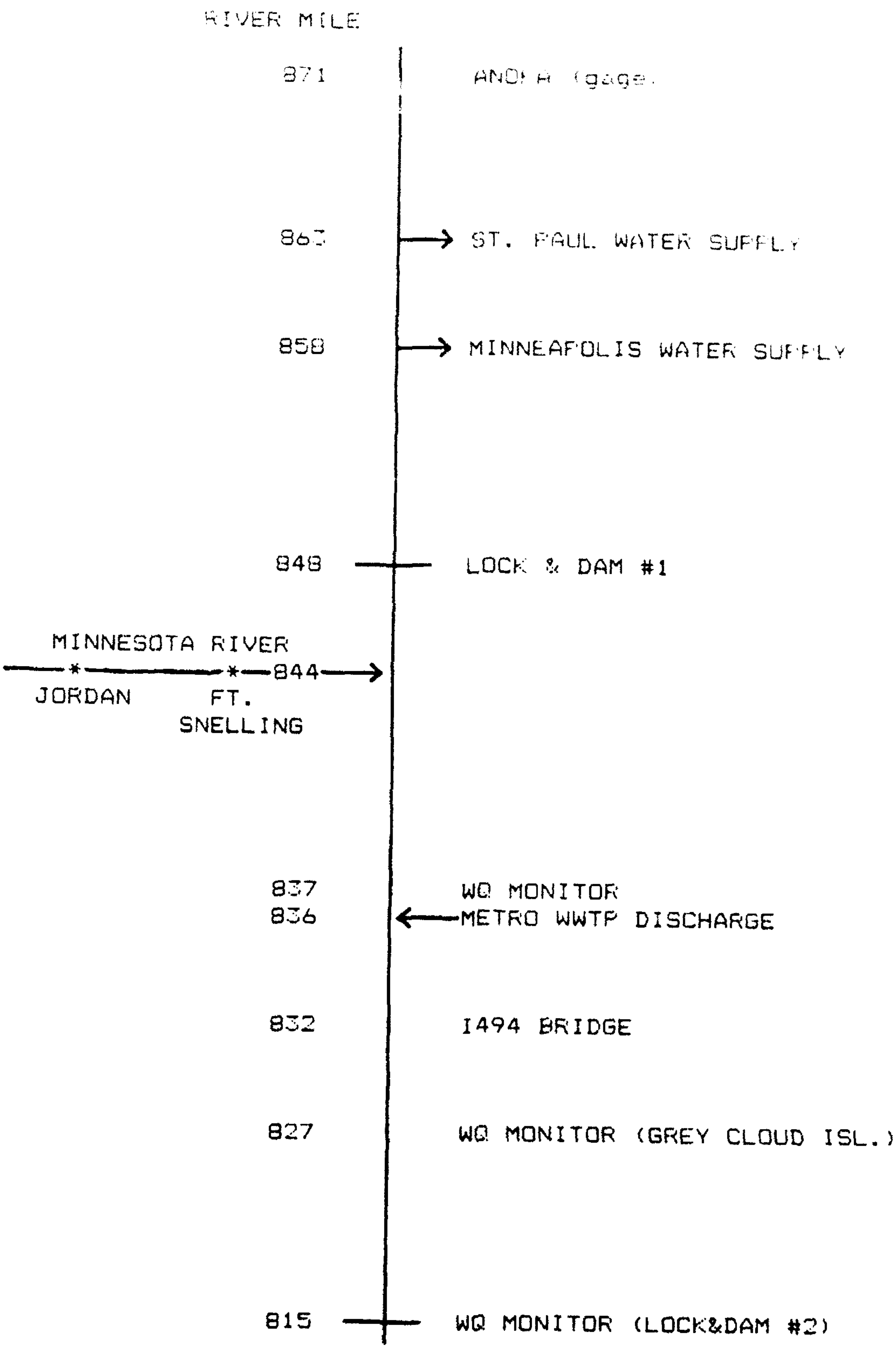


FIGURE 1

members of the Leech Lake Indian Reservation who argued that lowering the lakes would result in economic losses to wild ricing and resort enterprises in the headwaters region. On August 16 a large storm delivered 2 to 12 inches of rain across much of the region, ending the drought and temporarily settling many of the related issues.

In anticipation of future droughts, the U. S. Army Corps of Engineers St. Paul District is conducting a drought contingency planning study. The study includes a review of the headwater reservoirs operations policy during low-flow periods with consideration for both instream flow requirements necessary to support aquatic life and specific municipal and industrial water supply needs in the Twin Cities metropolitan area. The purpose of this paper is to evaluate flow augmentation as a means of improving water quality conditions in Pool #2 during extreme low-flow periods.

BACKGROUND

Although the Mississippi River is affected by numerous pollution sources prior to entering the Twin Cities metropolitan reach, the first major source of municipal and industrial pollutant loading normally occurs within navigation pool #2 at river mile 836.8, the point of discharge of the Twin Cities metropolitan wastewater treatment plant. Figure 1 describes the metropolitan reach of the Mississippi River between Anoka and Lock & Dam

#2 at Hastings, indicating the locations of water control structures, the Twin Cities water supply intakes and wastewater discharge, the mouth of the Minnesota River, and the water quality monitoring stations referred to in this study.

Figure 2 compares the May - September, 1988 daily flows on the Mississippi River at Anoka and the Minnesota River at Jordan with the 1935 - 1987 mean monthly flows for those stations. During June, July and into August both rivers were flowing at less than 20% of their historic means. On July 30 the gage at Anoka recorded a record low of 842 cfs. The water supply withdrawals of Minneapolis and St. Paul averaged about 300 cfs, leaving only 700 cfs or less flowing into Pool 2 during much of July and August. The 7-day (sustained) 10-year (frequency) low flow at St. Paul, the flow criterion which determines minimal wastewater treatment design, is 1708 cfs. The flow at St. Paul remained below that level for 48 consecutive days during June through August. The flow of the Minnesota River, as recorded at Jordan, Mn, likewise remained at an extremely low level throughout the summer. Its contribution of 200 to 300 cfs during July and August made up a large fraction of the Pool 2 flow especially within the reach above the metro plant discharge. The metro plant also delivered about 300 cfs. Thus about half of the flow in the lower reach of Pool 2 came from the Minnesota River and the wastewater treatment plant.

STUDY APPROACH

After many discussions with individuals having extensive experience with water quality conditions in Pool 2, it was concluded that existing mathematical models could not adequately simulate an extreme low-flow condition. Thus it was determined that the best way to evaluate potential benefits of supplemental flows would be to observe the response of the system to a naturally elevated flow event. Such an event, in fact, accompanied a storm occurring in mid-August. The flow augmentation by the storm came from only the reach of the Mississippi River above the confluence of the Minnesota River. It differed from the proposed 200 to 300 cfs supplemental flow in that it delivered about 4000 cfs of additional flow. The Minnesota River hydrograph (Fig. 2) was unaffected by the storm.

The case for flow augmentation is generally based on the benefits of dilution of pollutants and increased capacity for assimilating organic loads. An excessive organic load may cause a decline in DO to an unacceptable level due to microbial respiration. Furthermore, labile organic loads that are not oxidized by respiration near the source of input move downstream, resulting in potential DO depletion over a long reach of river. Thus the benefits of supplemental flows are a potential increase in dissolved oxygen concentrations, more efficient dilution and breakdown of organics, and possible reduction of the labile organic load that can affect downstream locations.

DATA ANALYSIS

The Metropolitan Waste Control Commission operates automated

water quality monitors at four locations; on the Minnesota River above its confluence with the Mississippi River (station MI 3.5)*, on the Mississippi River above the metro plant (UM 836.8), below the metro plant near Gray Cloud Island (UM 826.6), and at Lock & Dam 2 (UM 815.3). The monitors record dissolved oxygen, pH, conductivity, and temperature every 15 minutes continually. The MWCC also conducted a low-flow water chemistry survey of the entire metropolitan reach of the Mississippi River and its tributaries on a weekly basis during the summer.

The conductivity data from the MWCC grab samples and auto-monitoring network suggest that the Mississippi River had a relatively low ion concentration as it entered the metropolitan reach. Based on conductivity, the ion concentration of the Minnesota River appeared to be at least three times as high as that of the Mississippi River as it entered Pool 2. The conductivity plots for the Pool 2 auto-monitoring stations (Fig. 3) demonstrate the dilution of Pool 2 following the August high-flow event, when the ratio of Mississippi River to Minnesota River water increased from about 3:1 to 16:1.

Figures 4 - 7 present un-ionized ammonia concentrations at four locations. The Minnesota standard (.04 mg/l) for un-ionized

* "MI [n]" denotes Minnesota River [n] miles above its mouth.

MISSISSIPPI & MINNESOTA RIVERS

1988 FLOW AND HISTORIC MEAN MONTHLY

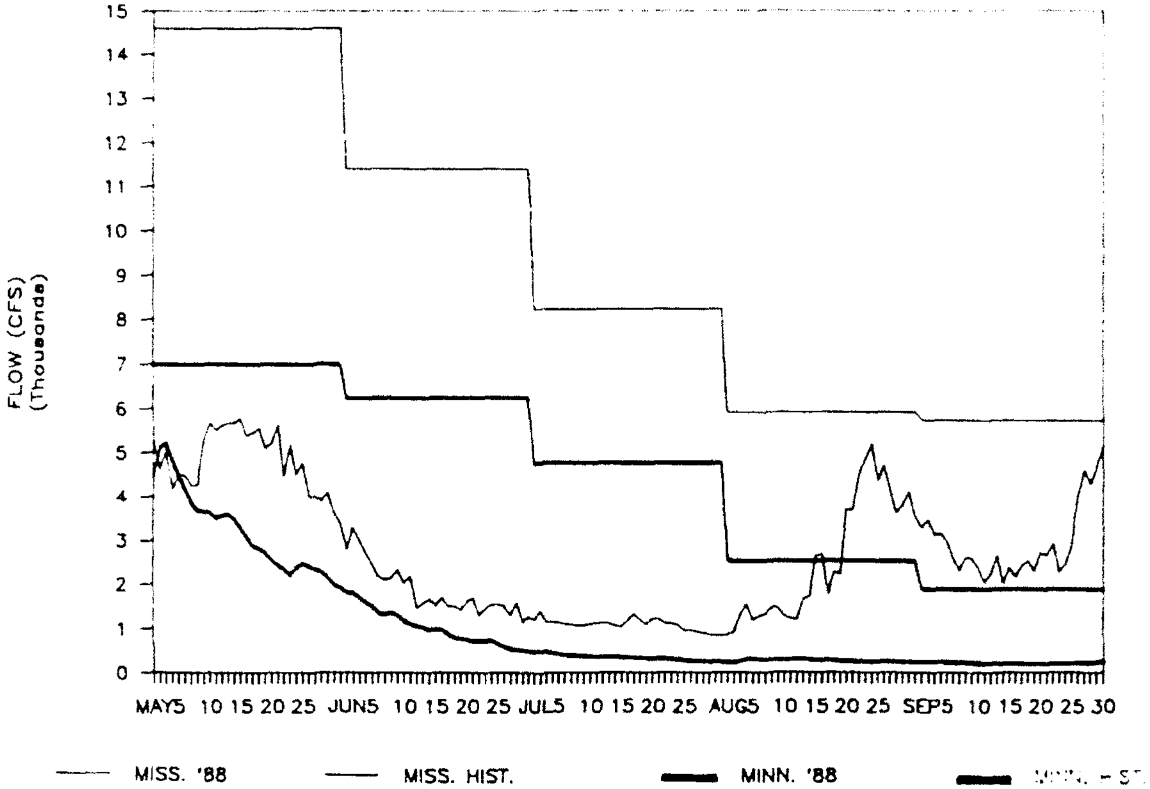


FIGURE 2

MISSISSIPPI & MINNESOTA RIVERS

1988 SPECIFIC CONDUCTANCE

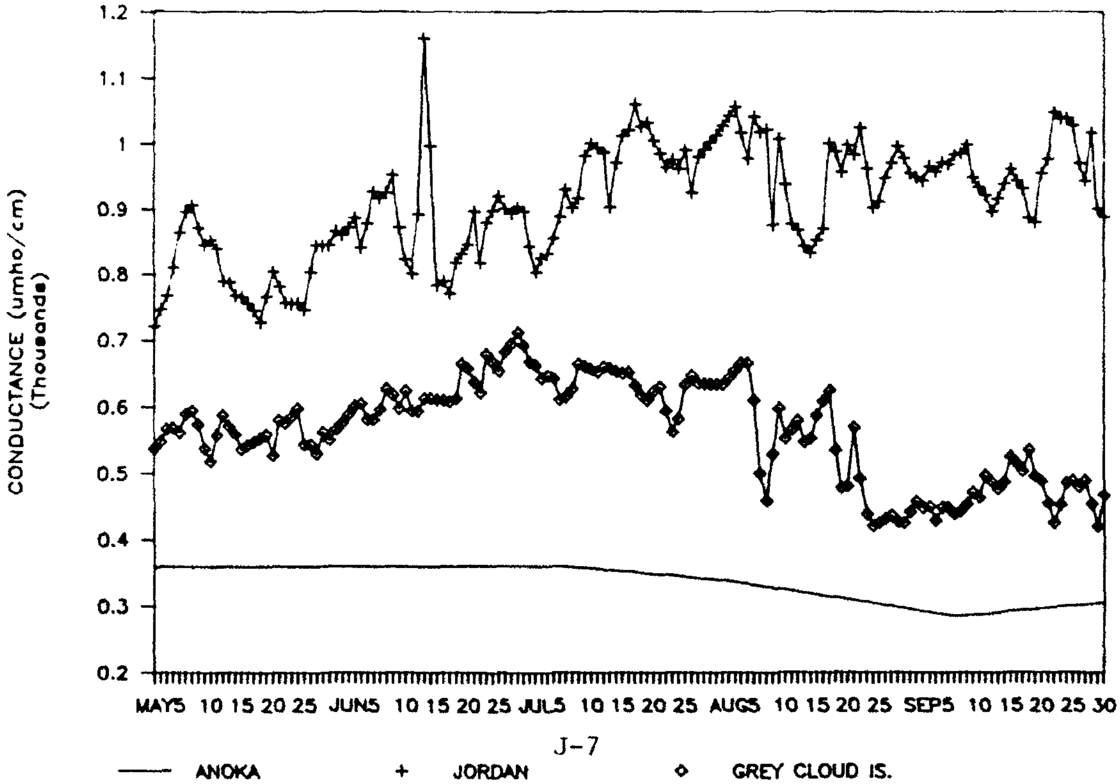


FIGURE 3

MISSISSIPPI RIVER AT LOCK & DAM 1

MWCC MONITORING DATA 1988

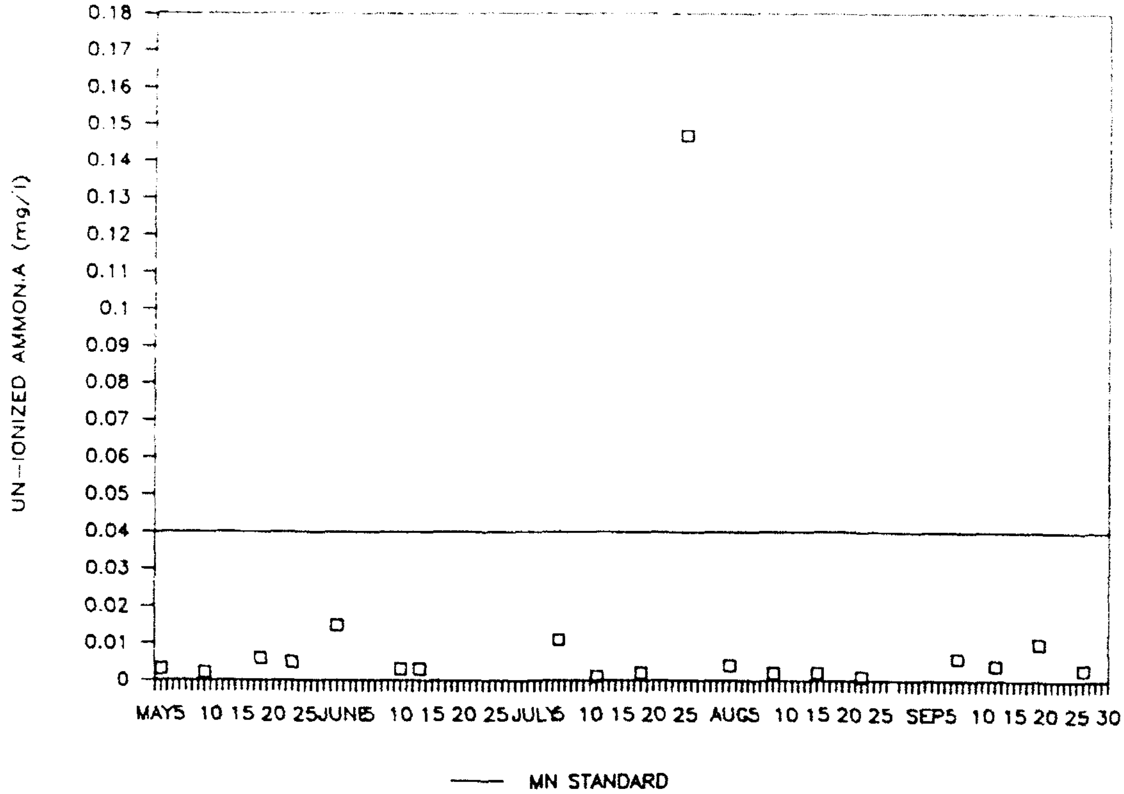


FIGURE 4

MINNESOTA R. AT FT. SNELLING

MWCC MONITORING DATA 1988

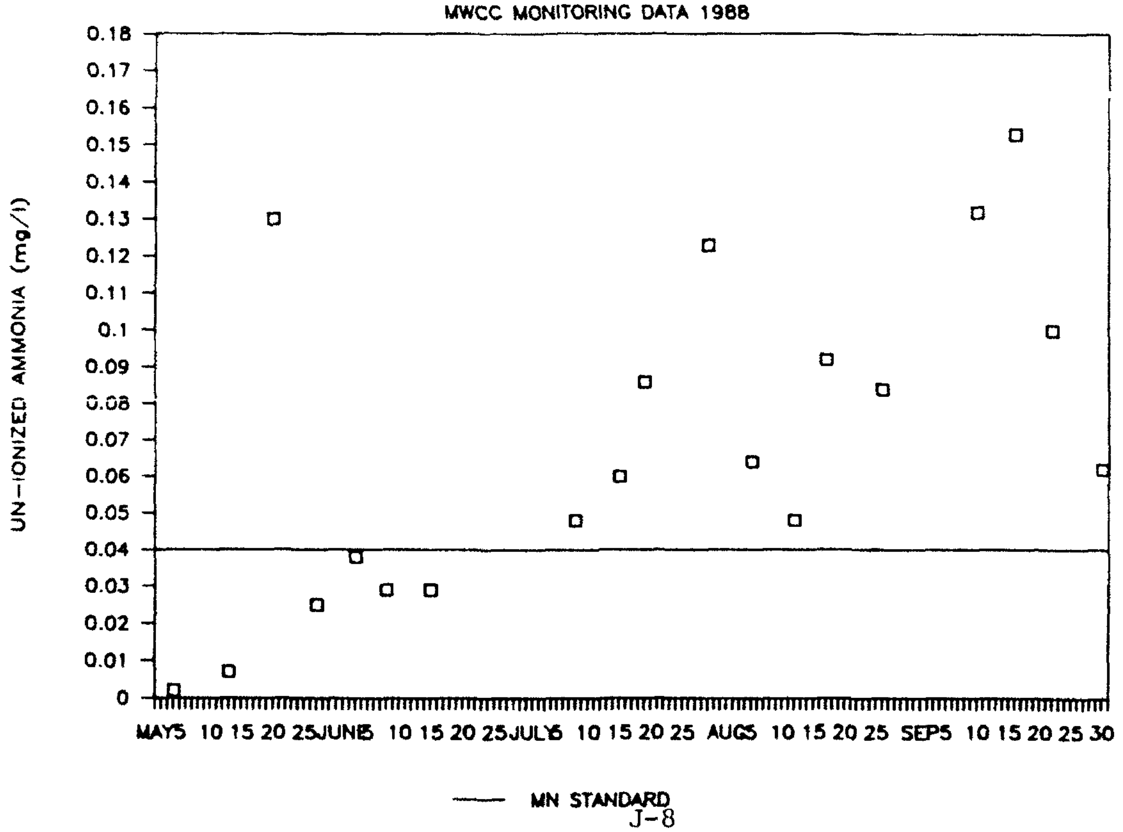


FIGURE 5

MISSISSIPPI RIVER AT GREY CLOUD ISLAND

MWCC MONITORING DATA 1988

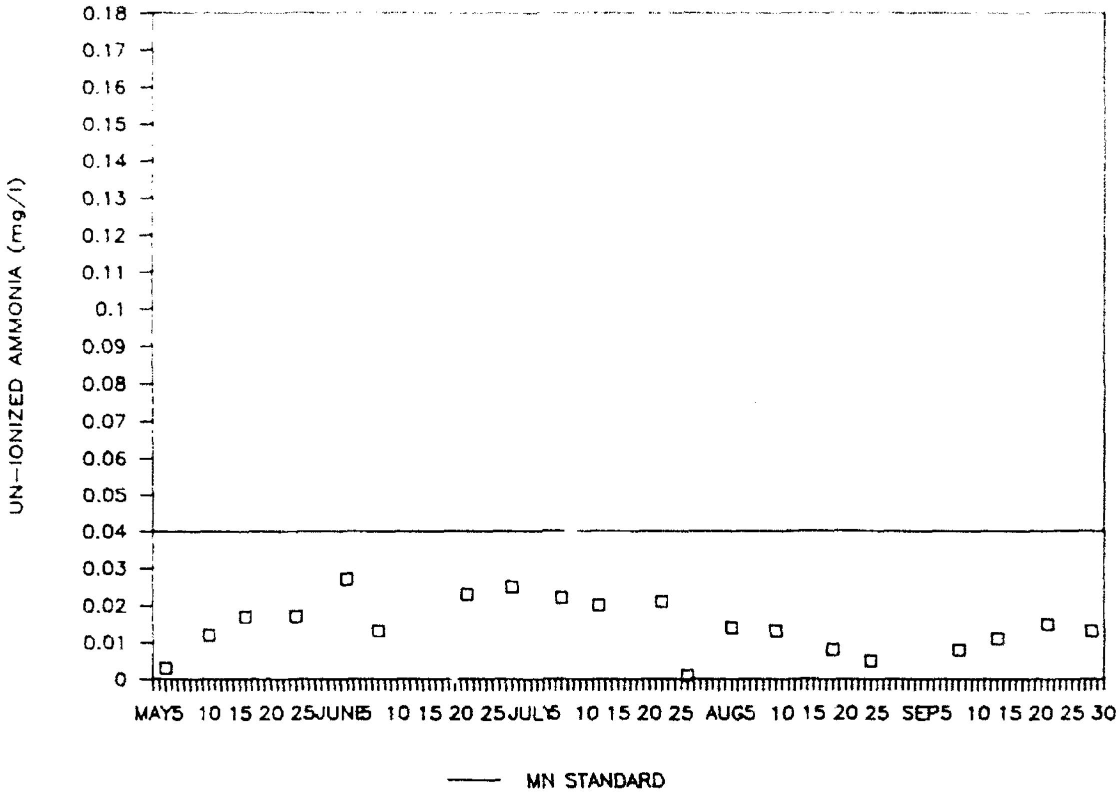


FIGURE 6

MISSISSIPPI RIVER AT LOCK & DAM 2

MWCC MONITORING DATA 1988

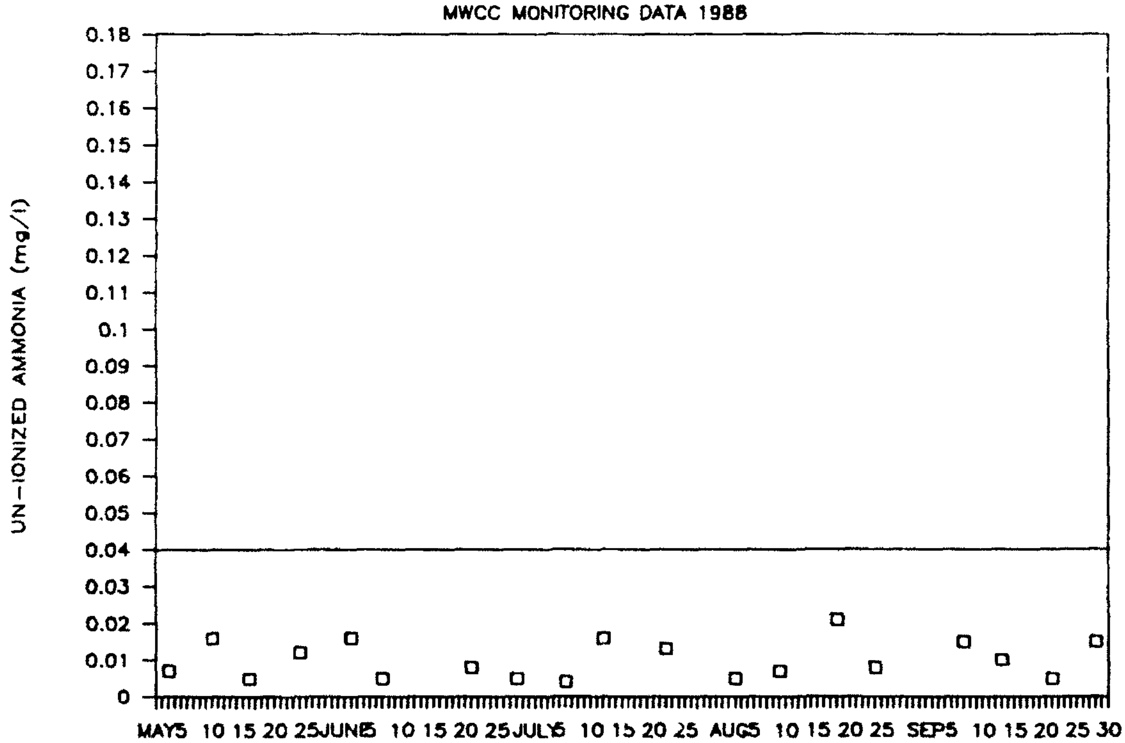


FIGURE 7

"UM" denotes Upper Mississippi River.

ammonia was not exceeded at any of the Mississippi River locations. The standard was exceeded on the Minnesota River at Ft. Snelling, where it enters Pool 2, in all samples during July, August, and September.

Figures 8 - 11 compare the 5-day biochemical oxygen demand (BOD5) at four locations. Most of the Pool 2 values fell within the range of 4 to 7 mg/l. Most of the Minnesota River values fell within the range of 6 to 8 mg/l.

Figures 12 - 15 present the chlorophyll-a concentrations at four locations. Most of the values at all locations fell within a range of 40 to 100 ug/l indicating an abundance of phytoplanktonic algae in both the Minnesota and Mississippi Rivers.

Figures 16 - 19 present the turbidity values at four locations. Most of the values for the Minnesota River at Ft. Snelling fall within the range of 15 - 25 ntu's (nephelometric turbidity units). Most of the values for the Pool 2 stations fall within the range of 5 - 10 ntu's.

Figures 20 - 23 present the daily dissolved oxygen minima and maxima for the Minnesota River near Ft. Snelling (MI 3.5); the Mississippi River above the metro plant discharge (UM 836.8); the Mississippi River at Gray Cloud Island, about 10 miles downstream of the metro plant discharge (UM 826.6); and the Mississippi River at Lock & Dam #2 (UM 815.3). The diel variation observed in the DO data is attributable primarily to metabolism

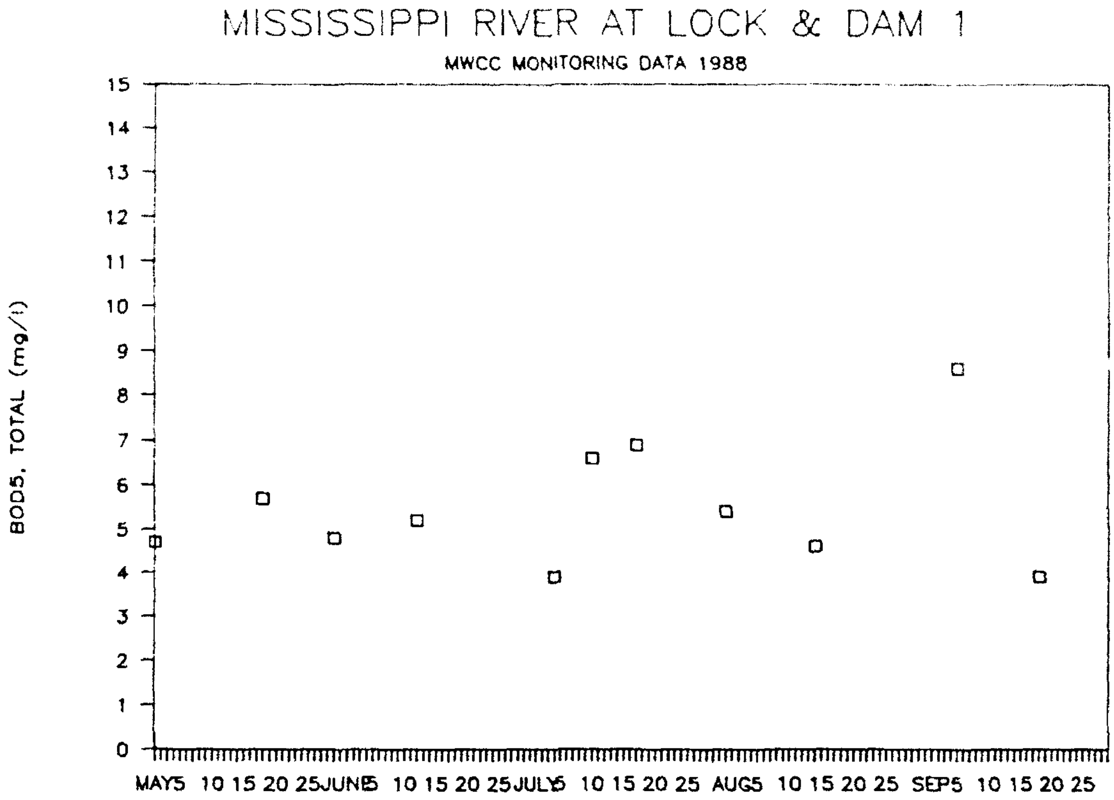


FIGURE 8

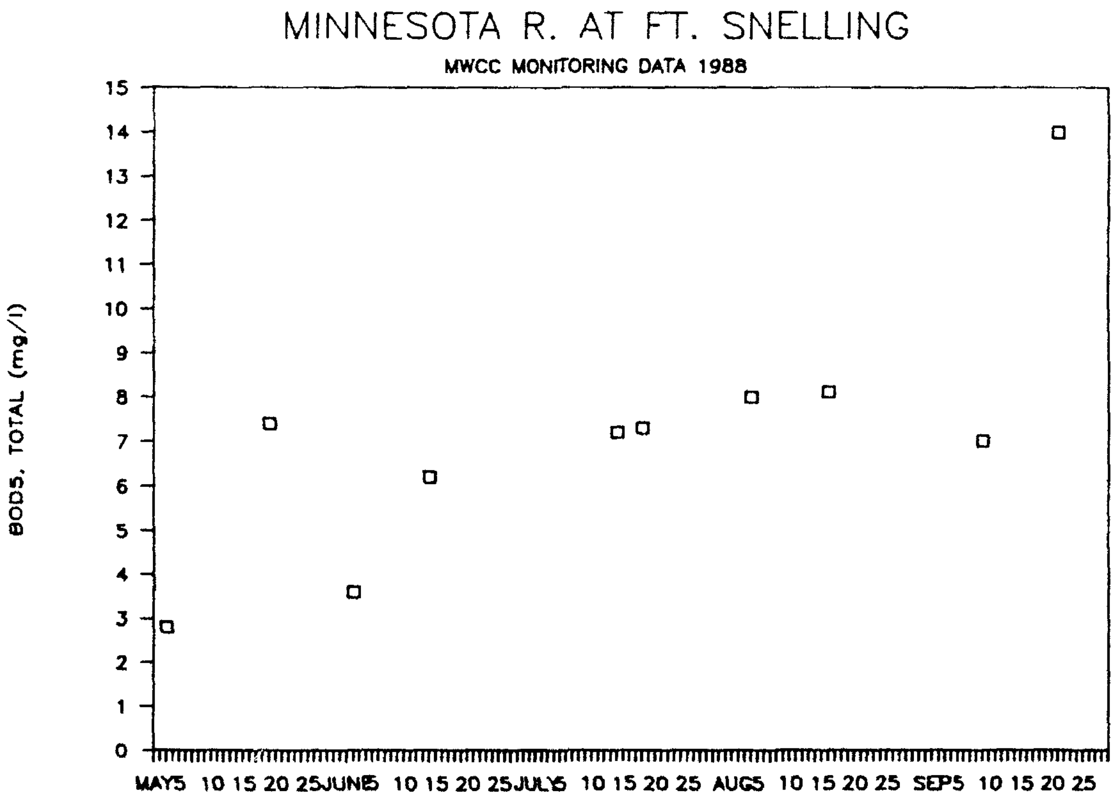


FIGURE 9

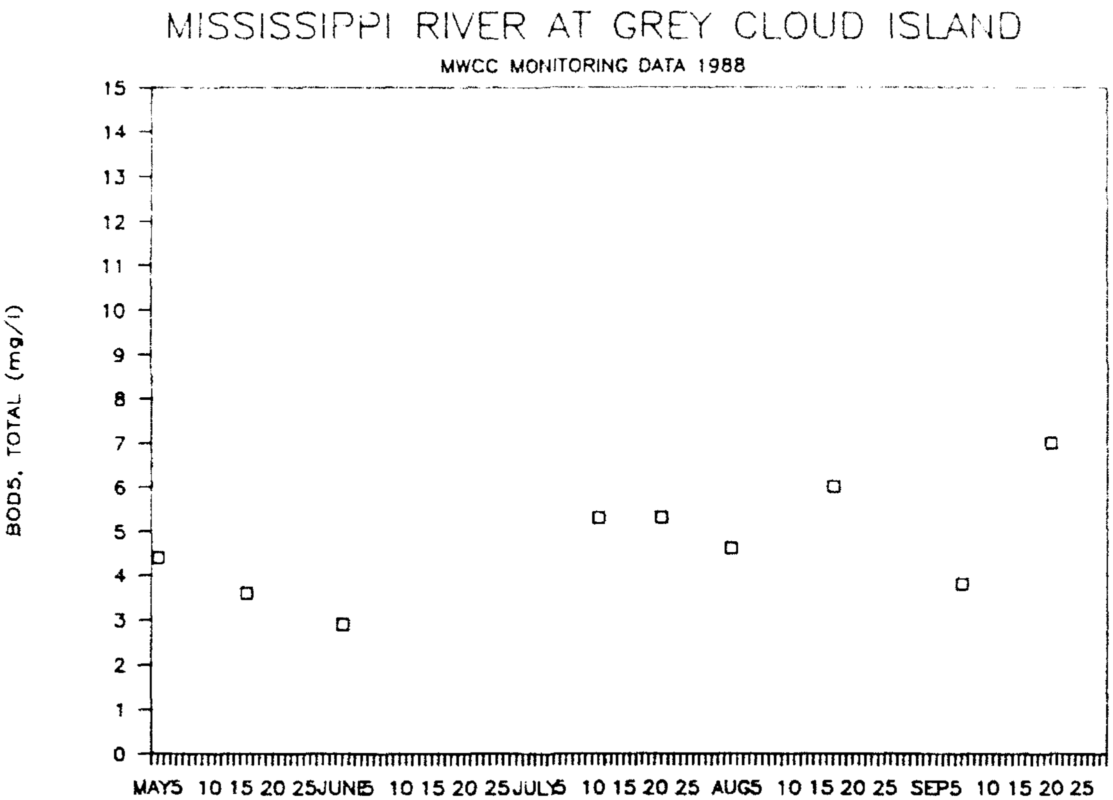


FIGURE 10

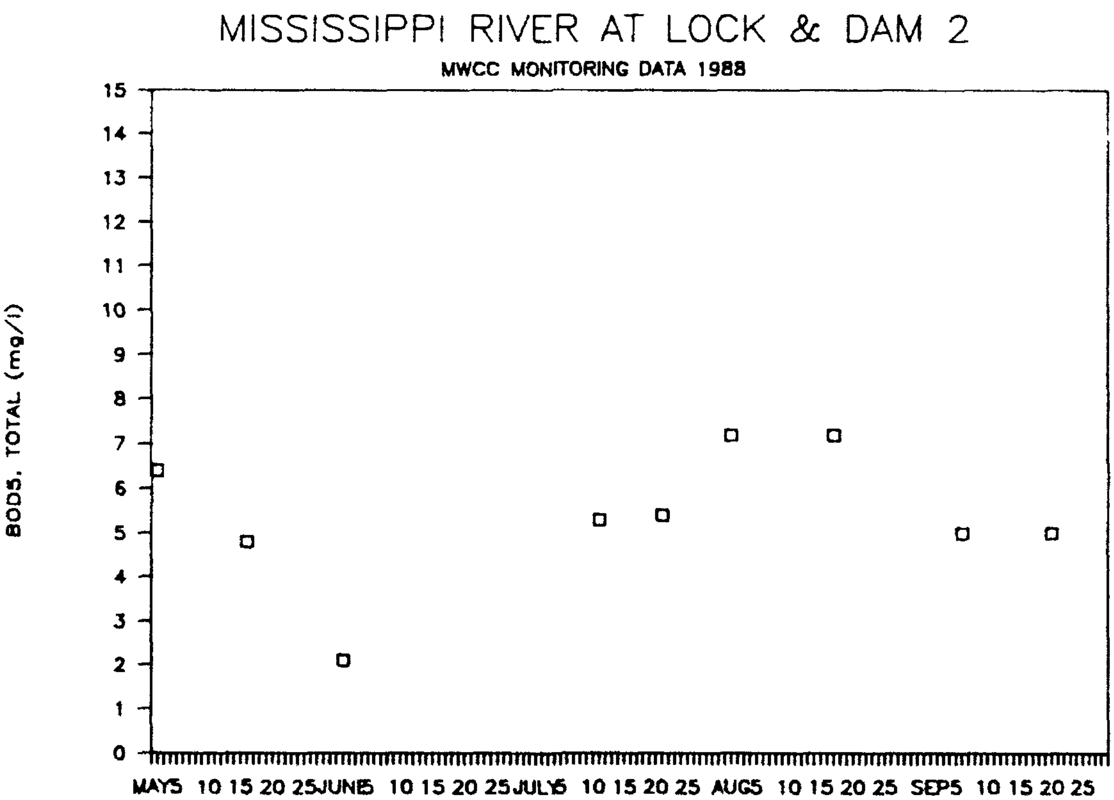


FIGURE 11

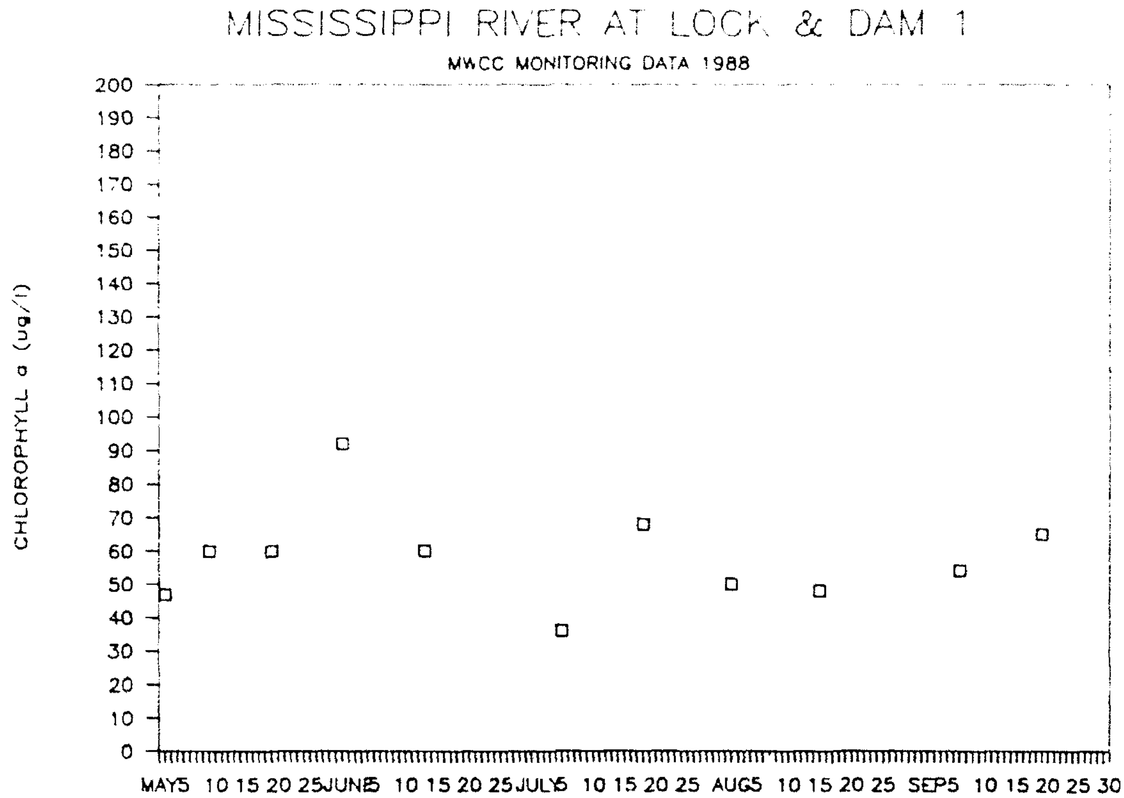


FIGURE 12

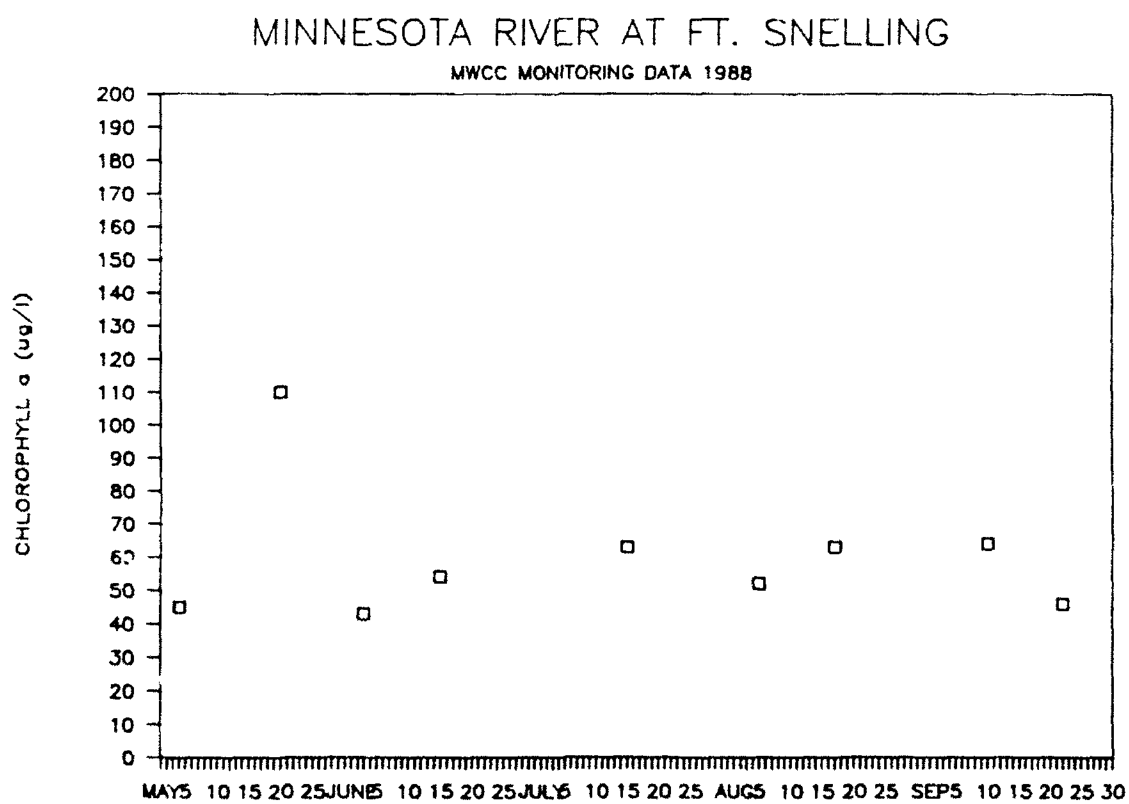


FIGURE 13

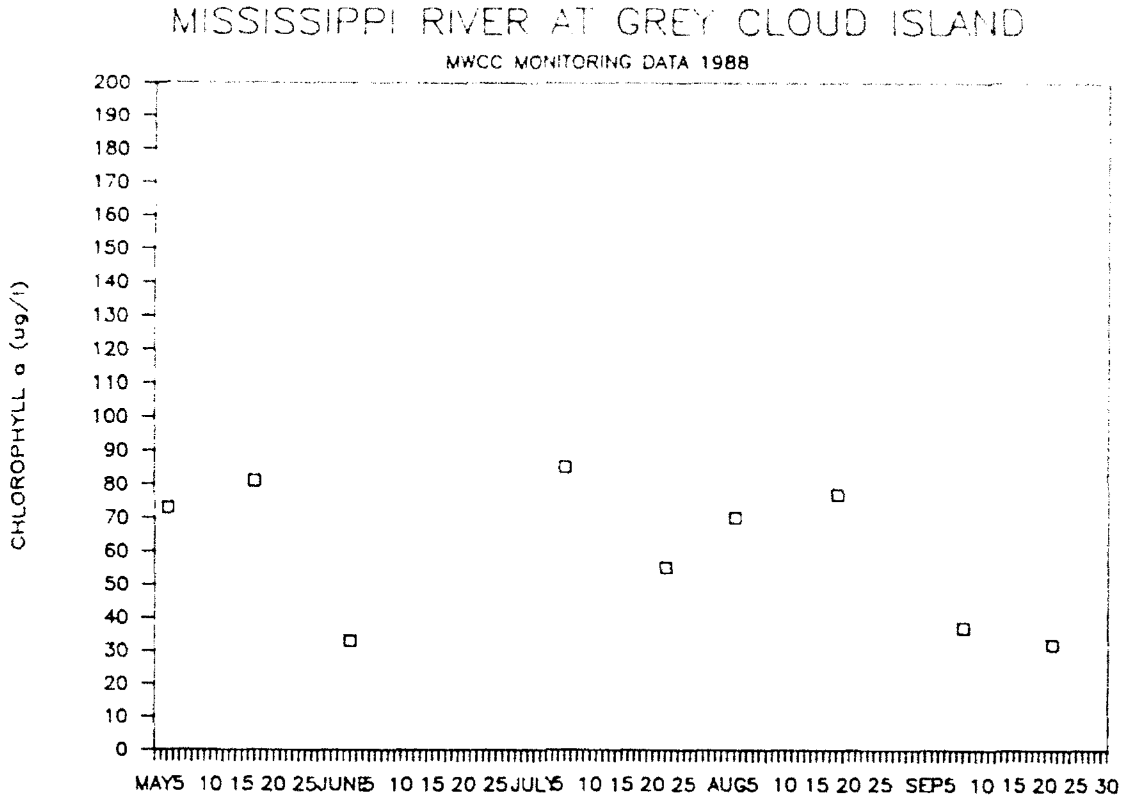
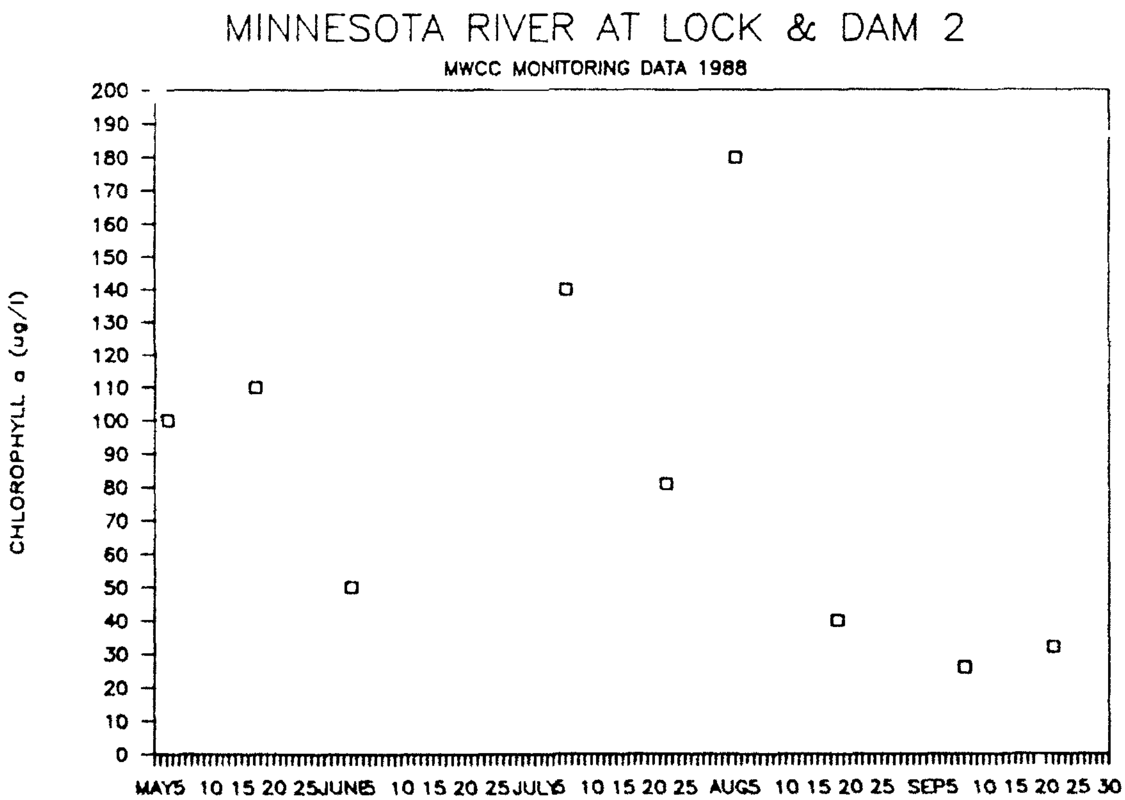

MISSISSIPPI RIVER AT GREY CLOUD ISLAND
MWCC MONITORING DATA 1988
CHLOROPHYLL a (ug/l)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MAY5 10 15 20 25JUNE5 10 15 20 25JULY5 10 15 20 25 AUG5 10 15 20 25 SEP5 10 15 20 25 30

FIGURE 14


MINNESOTA RIVER AT LOCK & DAM 2
MWCC MONITORING DATA 1988
CHLOROPHYLL a (ug/l)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
MAY5 10 15 20 25JUNE5 10 15 20 25JULY5 10 15 20 25 AUG5 10 15 20 25 SEP5 10 15 20 25 30

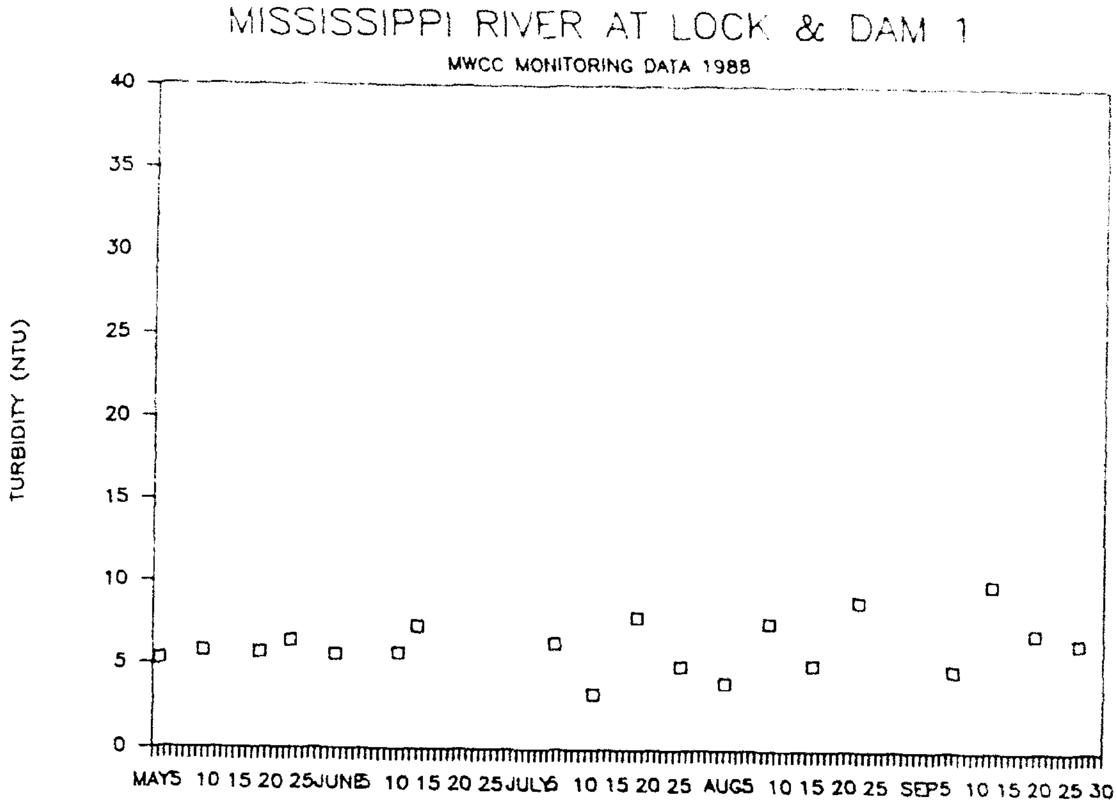


FIGURE 16

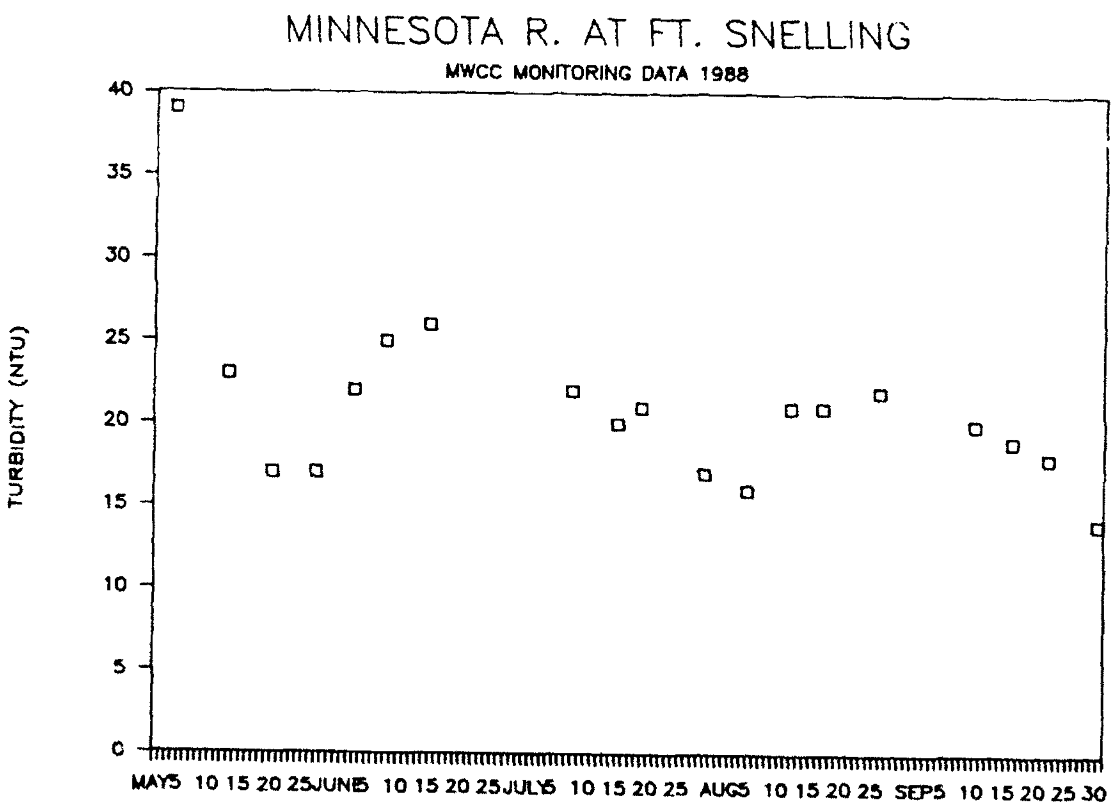


FIGURE 17

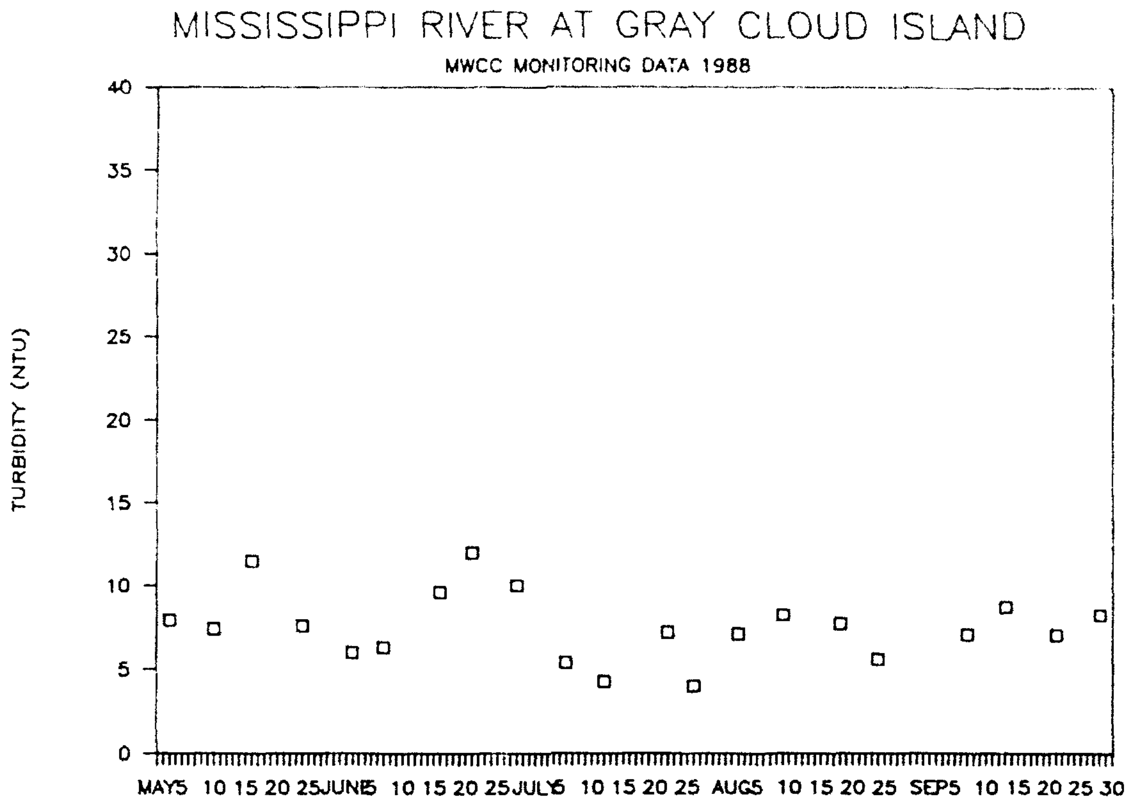


FIGURE 18

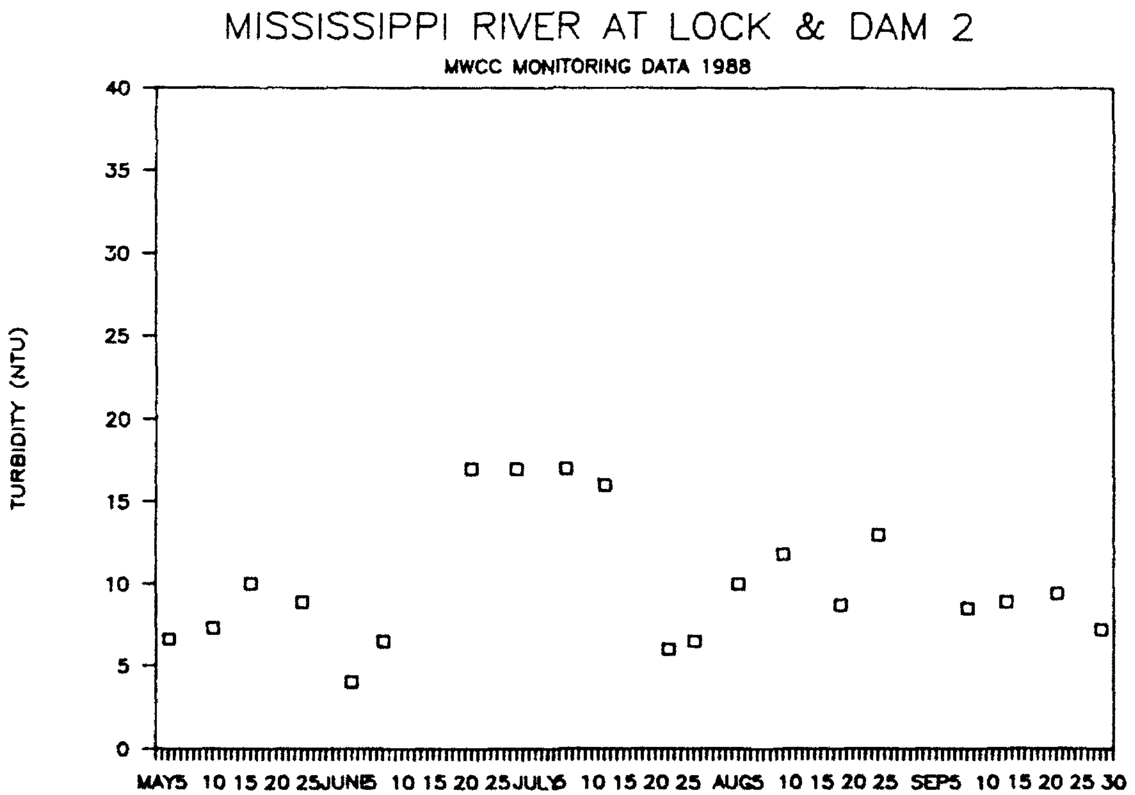


FIGURE 19

MINNESOTA R. AT FT. SNELLING

MWCC AUTOMATIC MONITOR 1988

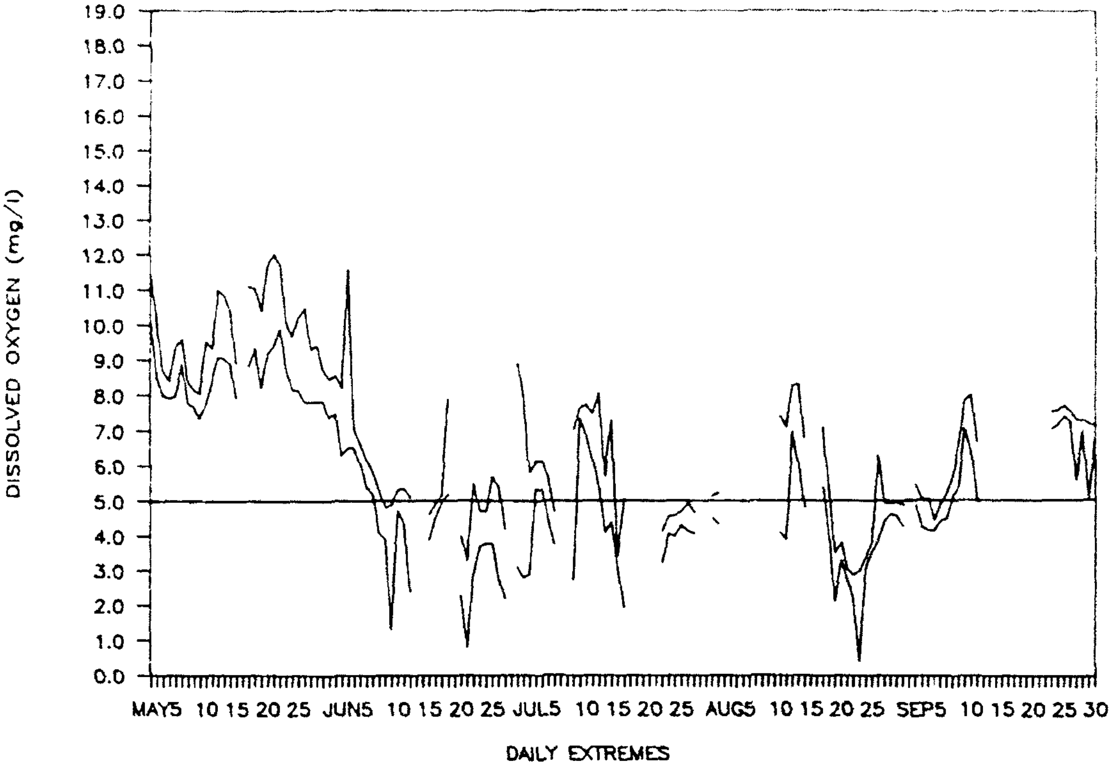


FIGURE 20

MISSISSIPPI RIVER ABOVE METRO PLANT

MWCC AUTOMATIC MONITOR 1988

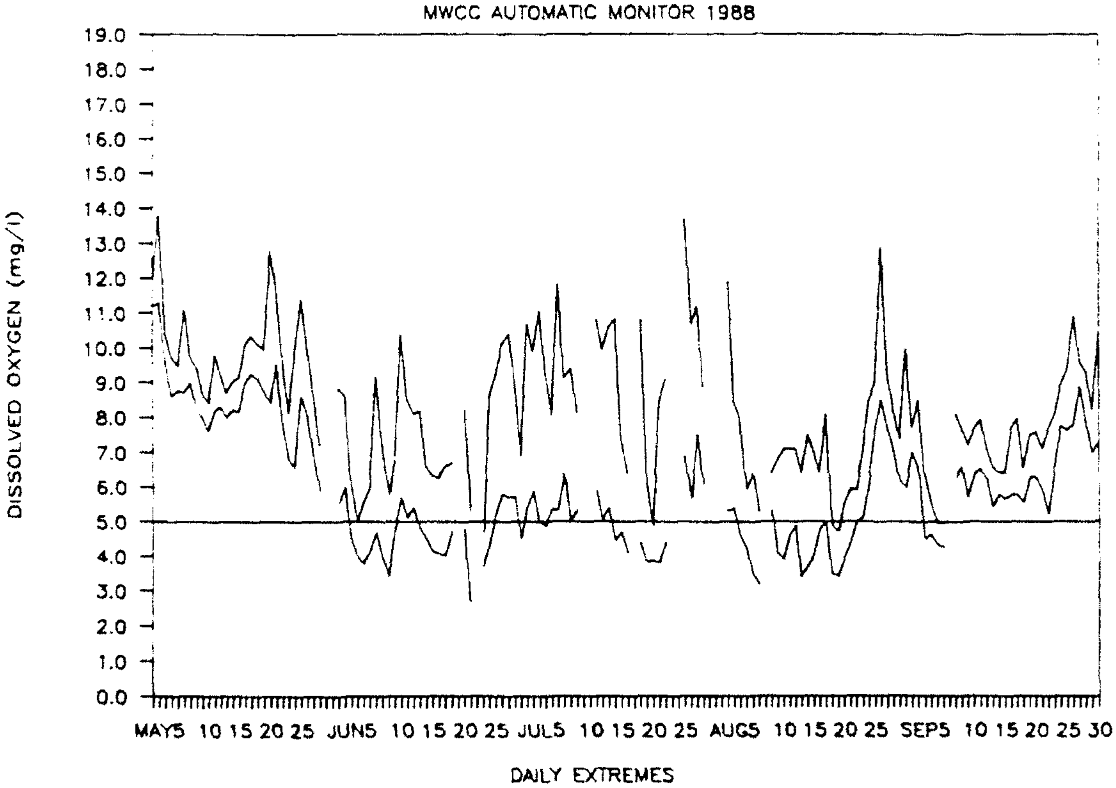


FIGURE 21

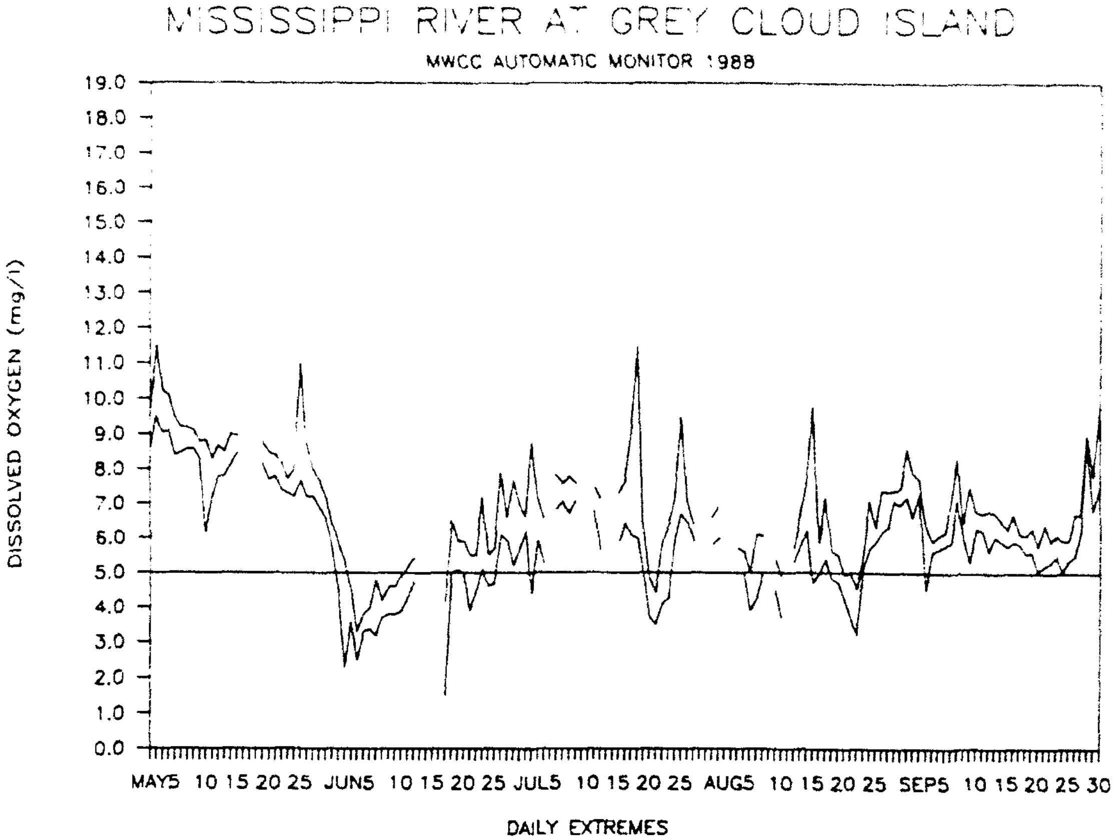


FIGURE 22

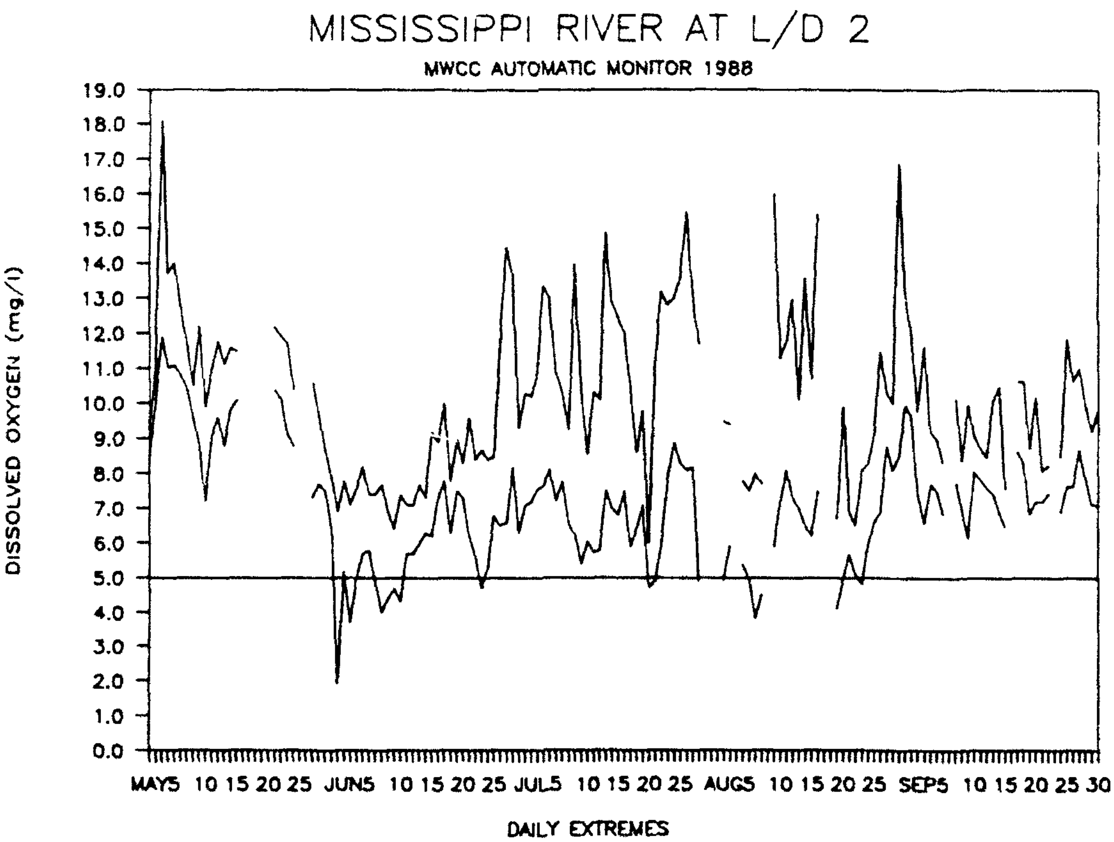


FIGURE 23

(photosynthesis and respiration) of planktonic algae. The DO plots from the Ft. Snelling station (Fig. 20) show that, beginning in early-June, the dissolved oxygen concentration began to vary within a range extending below the 5 mg/l state standard.

The DO plots at the station in Pool 2 above the metro plant (Fig. 21) show that dissolved oxygen concentrations began to fall below the 5 mg/l level as the flow at Anoka dropped below 2000 cfs. Diel variation was rather high, however, with daytime peaks usually in the supersaturation range. The condition persisted throughout the summer with brief periods of improved conditions in late July and late August.

The DO plots for the station at Grey Cloud Island (Fig. 22) show that dissolved oxygen concentrations fell rapidly into a low range in late May as the flow at Anoka fell below 2000 cfs. On 2 June the MWCC began to aerate the effluent from the metro plant to a DO concentration of 8 mg/l. This operation continued throughout the summer. The DO continued to fall frequently below 5 mg/l but the plot suggests that the aeration may have elevated the daily minima by as much as 2 mg/l. The diel variation was very low compared with the other Pool 2 stations.

The DO plots for Pool 2 at Lock & Dam #2 (Fig. 23) show that dissolved oxygen concentrations remained above the 5 mg/l level most of the time with only a few incidents of daily minima falling below 5 mg/l. Again, the plot suggests that the effluent aeration sustained the daily minima at a higher level. The diel variation at this location was very high compared with the Grey

Cloud Island station. The daily maxima often extended well into the supersaturated range.

DISCUSSION

The concern over the potential for a major fish kill due to dissolved oxygen depletion in Pool 2 during the summer of 1988 is founded in the knowledge that flow plays a major role in the dissolved oxygen economy of the riverine aquatic system by promoting diffusive exchange with the atmosphere and by providing buffer storage for satisfying peak respiratory demands. During low-flow periods the system becomes more reliant on primary producers (algae) for DO sustenance. The case in which both flow and primary production become insufficient to maintain DO levels is illustrated in the Ft. Snelling data showing persistent DO deficiency and excessive un-ionized ammonia concentrations (Fig. 5).

Dissolved oxygen plots of the daily minima and maxima provide two useful kinds of information. They indicate (a.) the degree and duration of the degraded conditions, and (b.) the level of metabolic activity (photosynthesis and respiration) which more than any other factor during low flow determines the availability of dissolved oxygen for fish and other animal life.

Dissolved oxygen concentrations of highly productive waters typically exhibit a diel periodicity which is driven largely by the metabolism of the aquatic plants and animals. Daily minimum values generally occur near dawn as respiratory demand has pre-

dominated during the hours of darkness. Daily maximums occur in the late afternoon as photosynthetic oxygen production has predominated during the hours of daylight. The magnitude of the diel variation is a reflection of the abundance and activity level of planktonic algae, animals, and bacteria.

All of the MWCC data represent surface samples, where the greatest dissolved oxygen diel variation is expected to occur. Figures 24 and 25 present the results of 24-hour 1-meter depth interval diel surveys conducted by the Corps of Engineers Waterways Experiment Station prior to and subsequent to the August storm event. The measurements were made near the I494 bridge (river mile 832). The data demonstrate that vertical DO gradients existed in Pool 2 and that the greatest diel variation occurred within the top 2 meters where the availability of light allowed phytoplankton to thrive.

The dissolved oxygen plot for station UM 836.8 (Fig. 21), located about .5 miles upstream of the metro plant discharge, indicates that, beginning in June, the daily minima dropped to or below the critical concentration of 5 mg/l nearly every night, but rebounded into the saturated and often the supersaturated range by day. The initial drop below the critical level occurred in early June corresponding with the flow at Anoka dropping below 3000 cfs. With the arrival of the supplemental flow of the August storm runoff, the daily minima remained above 5 mg/l for about two weeks. The subsequent drop back to the 5 to 6 mg/l range corresponds with the Anoka flow dropping again to about 3000 cfs (see Anoka hydrograph Fig. 3). The same pattern appears

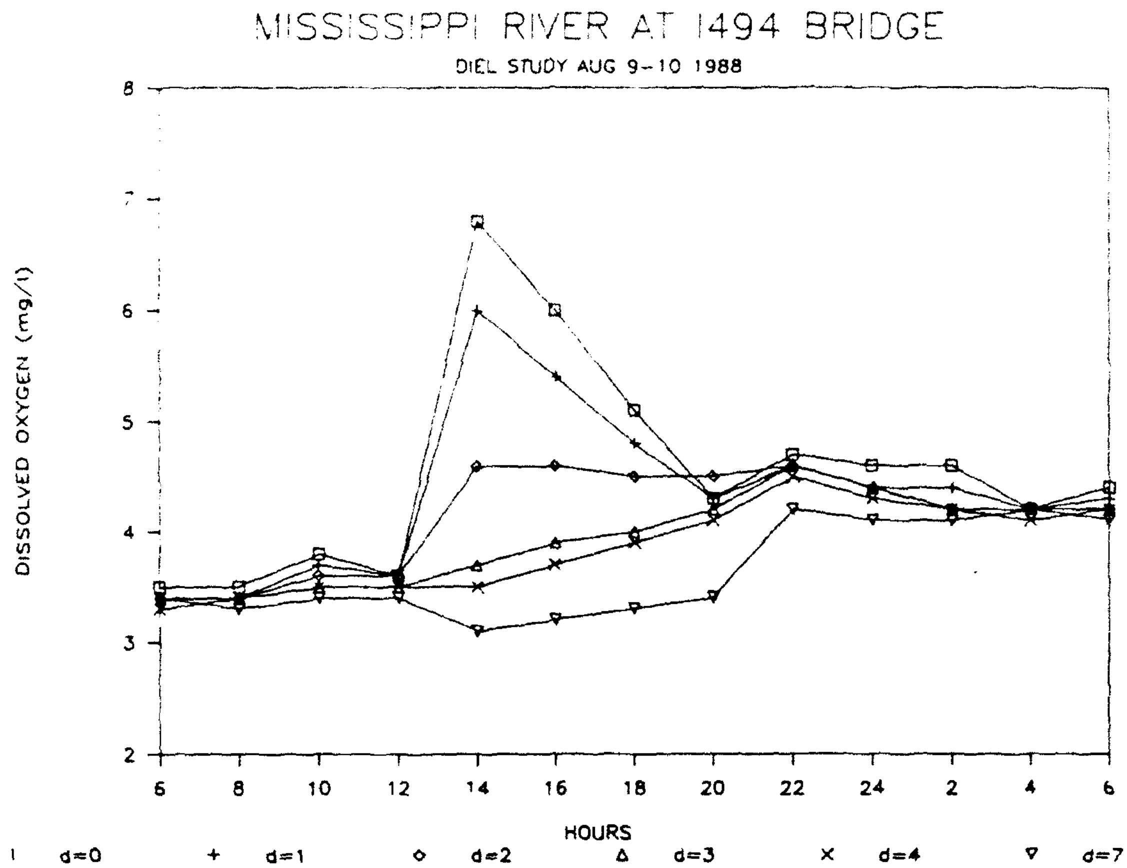


FIGURE 24

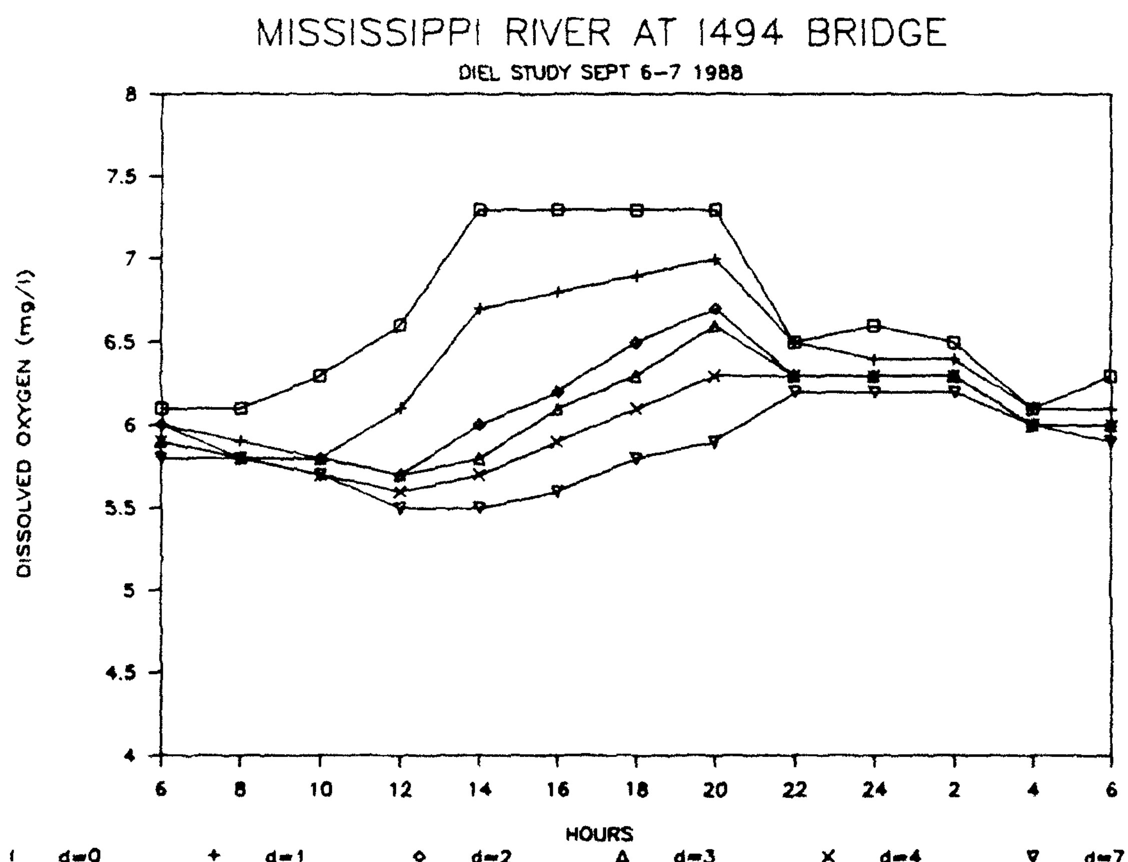


FIGURE 25

in the DO plots of the other Pool 2 stations (Figs. 22 and 23). Thus, the flow rate of 3000 cfs at Anoka appears to be the minimum needed to sustain dissolved oxygen levels above the 5 mg/l level in Pool 2.

The occurrence of depressed DO levels upstream of the metro plant is thought to have been related to the severely depressed DO and relatively high levels of BOD5, un-ionized ammonia, and turbidity that occurred in the Minnesota River. The relatively low diel dissolved oxygen variation that was observed in the Minnesota River would usually indicate low primary productivity. This is inconsistant, however, with the high levels of chlorophyll-a (40 - 50 ug/l). The suppressed diel range, therefore, suggests that either that the productivity of the algae was limited by turbidity or that the daily peak values were attenuated by a high rate of respiratory and chemical demand.

The DO plot for station UM 826.6 near Grey Cloud Island (Fig. 22) exhibits a pattern common also to the Lock & Dam 2 plot (Fig. 23) but absent from the upstream plots. The plots show that during the last week in May the DO concentrations, especially the daily minima, were dropping at an alarming rate and then recovered somewhat during the first week in June. The beginning of the recovery corresponds with the day, 2 June, when the MWCC activated their effluent aeration system at the metro plant. The system continued to operate throughout the summer, providing oxygen-saturated flow (about 8 mg/l).

At station UM 826.6 near Gray Cloud Island the dissolved oxygen diel variation was rather limited (Fig. 22), suggesting

low productivity. The daily minima dropped below 5 mg/l less frequently than they did upstream of the metro plant but the maxima were significantly lower than at the upstream station. The pattern may have been affected by the metro plant whose discharge was probably lacking of primary producers but high in bacterial load. The effect would be dilution of the algal density and attenuation of daily DO peaks by microbial demand along a limited reach of the pool.

At station UM 815.3 near Lock & Dam #2 the dissolved oxygen diel variation indicates the presence of a very productive algal population (Fig. 23). The daily minima usually remained well above 5 mg/l while the daily maxima often exceeded 150% of DO saturation.

CONCLUSION

Dissolved oxygen conditions in Pool 2 are determined largely by the metabolic activity of planktonic algae and by the quality and quantity of tributary flow. During the summer of 1988 the flow of the Mississippi River was so low that the contributions of the Minnesota River and the discharge from the Metropolitan Wastewater Treatment Plant became proportionately large. The Mississippi River contributed water with abundant planktonic algae but largely unaffected by oxygen-demanding pollutants. The Minnesota River contributed highly turbid, oxygen-deficient water, affected by point and non-point source pollution. The Metropolitan Wastewater Treatment Plant contributed stabilized

and clarified wastewater effluent which was mechanically aerated to saturation prior to discharge into Pool 2. A storm in August caused the Mississippi River's contribution to increase by 2000 to 3000 cfs during a two-week period. The dissolved oxygen condition of pool 2 improved significantly for as long as the flow remained above about 3000 cfs, but reverted to the degraded condition as the flow dropped below that level in September. Thus a flow augmentation of only 200 or 300 cfs from the headwaters reservoirs would probably produce an unmeasurable improvement during extreme low-flow periods.

APPENDIX K

EFFECTS OF EMERGENCY LOW FLOW RELEASES ON ECONOMIC/RECREATION RESOURCES OF THE HEADWATERS LAKES PROJECT AREA

APPENDIX K

Economic/Recreational Impacts - Supplemental Releases

The headwaters lakes offer a wide variety of water-based recreational activities. However, fishing by boat is by far the most popular activity. Boating use of the lakes can be diminished by water level fluctuations, including those caused by reservoir regulation. The low flow plan for the projects normally maintains an established water elevation for each lake. Under emergency conditions, the Corps of Engineers might decide to release supplemental flows, in addition to normal low flow discharges. In the event of emergency supplemental releases, a comparative evaluation procedure to account for diminished recreational benefits caused by the supplemental releases was developed and is described below. This and other information could then be used by the Corps of Engineers to select the least damaging way to make emergency supplemental releases. This information is not intended for making the decision as to whether or not to make emergency supplemental releases, but rather to assist in determining how to make emergency releases from the six headwaters lakes.

The first step in developing a model of lake water level effects on boating related income was to determine which lakes are affected by dropping water levels in the six project lakes. All six project lakes are connected to smaller, non-project lakes. When the levels of the project lakes drop, then boating on non-project lakes can also be affected. A review of topographic maps and the reservoir operating manuals and discussions with Corps of Engineers Headwaters staff, Department of Natural Resources (DNR) personnel, and resort owners were used to identify the lakes that are affected by the operation of the 6 projects. Eliminated from further analysis were those lakes that are only affected by high water levels; those that did not contain any private residential development, public access, or resorts/marinas/campgrounds; and those in which the effects are minute. See Table I for a listing of lakes selected for supplemental flow evaluations.

TABLE K-1 - LAKE EVALUATION

Gull Lake Chain

1. Gull (includes Lower Gull)
2. Nisswa
3. Round
4. Upper Gull
5. Upper Cullen
6. Middle Cullen
7. Lower Cullen
8. Margaret
9. Roy
10. Ray
11. Spider
12. Love

Leech Lake Chain

1. Boy
2. Kabekona
3. Leech (includes Benedict)
4. Steamboat
5. Swift
6. Portage

Sandy Lake Chain

1. Aitkin
2. Big Sandy
3. Flowage
4. Sandy River
5. Davis
6. Rat

Pine Lake Chain

1. Arrowhead
2. Bertha
3. Big Trout
4. Clamshell
5. Cross
6. Daggett
7. Little Pine
8. Lower Hay
9. Pig
10. Rush
11. Lower and Upper Whitefish (includes Island and Loon [Hat])
12. Upper Hay

Winnibigoshish Lake Chain

1. Cutfoot Sioux
2. Little Cutfoot Sioux
3. Sugar
4. Winnibigoshish

Pokegama Lake Chain

1. Blackwater
2. Jay Gould
3. Little Jay Gould
4. Pokegama

TABLE K-2
INVENTORY OF PRIVATE RESIDENCES, PUBLIC ACCESS PARKING SPACES, & LODGING/CAMPING UNITS

	Private Residences	Parking Spaces	Lodging Camping Units
Gull Lake Chain			
1. Gull (includes Lower Gull)	490	79	652
2. Nisswa	60	0	0
3. Round	232	22	0
4. Upper Gull	18	0	0
5. Upper Cullen	27	0	59
6. Middle Cullen	96	8	32
7. Lower Cullen	118	0	27
8. Margaret	18	0	0
9. Roy	118	0	0
10. Ray	19	0	0
11. Spider	0	0	55
Leech Lake Chain			
1. Boy	87	0	42
2. Kabekona	193	10	11
3. Leech (includes Benedict)	733	120	1384
4. Steamboat	42	2	16
5. Swift	24	0	0
6. Portage	20	3	0
Sandy Lake Chain			
1. Aitkin	2	0	24
2. Big Sandy	868	28	69
3. Flowage	32	12	0
4. Sandy River	35	0	0
5. Davis	11	0	0
6. Rats	22	0	0
Pine Lake Chain			
1. Arrowhead	29	0	0
2. Bertha	142	0	12
3. Big Trout	269	0	0
4. Clamshell	110	23	26
5. Cross	527	55	14
6. Daggett	201	0	0
7. Little Pine	87	0	140
8. Lower Hay	103	20	9
9. Pig	65	4	8
10. Rush	231	0	27
11. Lower and Upper Whitefish (includes Island and Loon [Hat])	895	0	138
12. Upper Hay	95	5	56
Winnibigoshish Lake Chain			
1. Cutfoot Sioux	1	96	30
2. Little Cutfoot Sioux	0	12	14
3. Sugar	5	0	0
4. Winnibigoshish	18	122	435
Pokegama Lake Chain			
1. Blackwater	1	0	0
2. Jay Gould	52	0	0
3. Little Jay Gould	56	20	0
4. Pokegama	825	32	46

The next step is to estimate the visitation to all the selected lakes. Boating hours was selected as the means to estimate visitation for several reasons. First, it is the dominant use in the Headwaters lakes because of the large number of anglers fishing from boats. Second, it was the only use for which research has been completed that provides enough information to make an estimate. Third, it is unclear that lowered lake elevations have a negative effect on other uses, such as swimming, walking/hiking, and biking. The DNR has developed a regional model that estimates that there are 667.41 boating hours supported by each parking space at a public access, 120 boating hours supported by private residences adjoining the lakes, and 420.67 boating hours supported by each camping/lodging unit. These figures are for the summer season only. An inventory of all the private residences, public access parking spaces, and lodging/camping units was provided by the DNR. The data for lodging/camping units was updated by a telephone survey of all resorts/campgrounds. Table II is an updated inventory of all private residences, public access parking spaces, and lodging/camping units for the selected lakes.

To measure the impacts on recreation due to different supplemental release scenarios, it was assumed that there is a positive correlation between lowered lake elevations and the loss of visitation that resulted from the loss of use of a facility (boat ramps and docks) and reduced navigability due to low water levels. As the lake elevation drops below the level needed for unimpaired use of a facility, there will be a gradual loss in use until it reaches an elevation at which the facility can no longer be used. The loss in use of a facility directly relates to a loss in visitation.

In order to apply the above assumption, the number of docks at the private residences had to be determined. To avoid the potential for double counting impacts, it was assumed that only 90 percent of the private residences had docks and that the remaining 10 percent would use the public access ramps and would therefore be accounted for through calculations for the public accesses.

Once a scenario elevation is determined, the percentage of remaining use is estimated for each facility unit (public access, private dock, lodging/camping unit) by estimating the remaining depth at each facility and applying increment factors. Increment factors were determined by making a straight line graph using the depth at which a facility is 100% usable and the depth at which all utility is lost at the facility. The increment factor is the amount of loss in utility for each 0.10 of a foot. Percentage of remaining use in turn determines the number of boating hours a facility is able to support under the supplemental release scenario. For example, a public access requires a minimum depth of 2.7 feet to retain full use. If the depth reaches 8 inches or below, utility is assumed to be zero. A lake level resulting in a depth at a public access of 2 feet corresponds to a percentage of remaining use of 65 percent. The percentage of remaining use is then applied to the number of boater hours supported by the public access (number of parking spaces x 667.41)(65%) to arrive at the number of boater hours generated by the public access under the particular scenario. This same method is used for each public access, each lodging/camping unit, and each private dock to come up with the remaining utility of the lake as a source of recreation.

This correlation method assumes that no action is taken to allow use to continue unimpaired (no cost to continue use has been calculated) and that it is a proxy for all the other impacts such as boaters having to be more cautious, docks having to be extended, other public accesses having to be used.

Determination of Recreation Benefits

Recreation benefits, both positive and negative, are measured in terms of aggregate willingness to pay. Total willingness of users to pay is the sum of two components: the actual entrance fees and user charges for the right to use the site plus any excess amount which they would be willing to pay but do not have to pay. Willingness to pay does not include payment made for other goods and services. The procedures to account for these other costs can be found in the section titled "Economic Calculations".

The determination of the recreational benefits created or lost by lowered lake levels is conceptually no different than estimating the recreational benefits associated with the development of a Corps project. The Ccrps uses three methods, travel cost, contingent value, and unit day value (UDV), to determine the NED (National Economic Development) recreational benefits of alternative plans. The objective of the procedure is to provide an inexpensive and quick comparative evaluation and not to provide precise benefit figures that more time and money would allow. Therefore, the UDV method, which is based on professional judgment and not widely encouraged as a means of determining actual benefit costs, was employed. This method is the simplest and least costly method to use.

The UDV is determined by using Table VIII-3-2 Guidelines for Assigning Points For General Recreation and Table VIII-3-1 Conversion of Points to Dollar Values. Both of these tables are found in ER 1105-2-40. Using table VIII-3-2, the following point values were assigned to the 5 evaluation criteria.

Criterion 1.	Recreation Experience - Value	16
Criterion 2.	Availability of Opportunity - Value	3
Criterion 3.	Carrying Capacity - Value	9
Criterion 4.	Accessibility - Value	14
Criterion 5.	Environmental Quality - Value	12
	Total Points Assigned	54

Using table VIII-3-1 and the 54 points determined from table VIII-3-2, the estimated UDV is $4.27. Since the DNR used hours in estimating visitation, the UDV had to be converted into unit hour value, UHV. Based on information obtained from the Waterways Experiment Station and from discussions with recreators, it was decided that 3 hours should be used for each unit day. Therefore, the UDV of $4.27 becomes a UHV of $1.42.

Using the estimated visitation at a given lake level scenario and applying the UHV, an estimate of the recreational benefits/impacts can easily be made. The recreation benefits are then added to the economic impacts to arrive at the total impact for the various scenarios.

Economic Calculations:

The headwaters lakes play a significant role in attracting tourists and tourists' dollars to the headwaters region of Minnesota. Consequently, any action by the Corps of Engineers that will affect the quality of the recreational experience on these lakes will have an impact on the regional economy.

This analysis attempts to measure on a relative lake to lake basis the economic impacts of releasing supplemental water from the headwaters lakes. Due to the tenuous link between lake levels and economic activity in the surrounding area, the results of this analysis by no means represent the definitive statement of economic impacts associated with given scenarios. The analysis does, however, allow for a useful comparison of potential impacts on a relative and equal basis.

The economic impacts considered here are undoubtedly regional. A less attractive vacation experience in the headwaters region will encourage people to simply recreate elsewhere rather than forego a hard earned vacation. From a national perspective, the effect on the national income resulting from supplemental releases of any or all of the headwaters lakes will be minimal.

To the regional economy, though, the headwaters lakes are an important resource. Resorts on the headwaters lakes account for approximately 40 percent of the total number of lodging units in the counties in which the lakes are located. Water related recreation expenditures account for 11.0 percent of employment in the Northeast economic region of Minnesota (all headwaters lakes are located in the Northeast region) compared with 2.1 percent for the State as a whole; 7.6 percent of gross output versus 1.6

percent for the State; and 7.6 percent of value added versus 1.5 percent for the State.

Lowering the lake level by supplemental releases reduces the utility of a lake as a source of recreation activity. Boat docks are either too high to safely enter boats or are less accessible as water depths beneath them become shallower. Launching boats off of boat ramps is more difficult with shallower water. Channels connecting lakes become less navigable and underwater hazards become more prevalent.

As lake levels fall, lakes become less attractive for recreators. This may happen whether the drop has a real or only a perceived effect on water dependent facilities. Due to media exposure and buildup of the negative aspects of supplemental releases, tourists may avoid an area even though the lakes may still offer a fully appealing recreation experience. Fewer recreators in an area mean reduced income for the local tourist industry. Occupancy of resorts and campgrounds is reduced; gas stations pump less gas; gift shops and restaurants serve fewer customers; fewer anglers buy bait and tackle; etcetera. Industries linked to the local tourist industry as suppliers of goods and services will also experience reduced income.

From a procedural standpoint, the economic analysis is simply an extension of the recreation impact analysis. The recreation analysis determines level of lake usage in boater-hours for given lake elevations. The economic impact analysis takes this a step further by quantifying the economic activity associated with the different levels of lake usage. In the example that follows, economic impact is measured using direct and indirect expenditures as indicators. Impacts on employment and value added can also be measured.

Based on expenditures data from the DNR, a boater-hour of use translates into a direct expenditure of $2.70. This holds true regardless of the source of the boating-hour: riparian residence, resort/campground lodging units, or public access parking spaces. Indirect income amounts to an additional $0.362 for every dollar of direct expenditure. This is the

income generated by the interbusiness transactions needed to supply the directly impacted business with inputs required to produce the consumer product.

The first step in evaluating economic impacts is to determine the level of recreational usage for the base or pre-release scenario. This is determined through the analysis of recreational impacts at the base water surface elevation. A description of this procedure appears in the previous section on recreational impacts.

Given the usage levels for the base scenario, the next step involves determining economic impact associated with these usage levels. The figures above are used to derive direct and indirect expenditures. The relationships between lake usage and these measures of economic activity are represented by the following equations.

Direct expenditures = Boater-hours x $2.70

Indirect expenditures = Direct expenditures x $0.362

The same process is followed for the supplemental release scenarios. The change in economic activity from the base scenario to the supplemental release scenario is considered the economic impact of the releases.

A DBase PC data base program has been prepared with the appropriate information so that only the projected lake levels need to be entered. The output from the spreadsheet provides figures to help compare the emergency release plans with each other. The effects on public use could then be displayed on a table for each alternative along with information about effects on all the other lake area resources. Should this data base program be used at some future date, the UHV, which changes annually, and the values for the economic calculations will need to be updated.

Example emergency water release plans were selected by the study team for the purpose of illustrating this procedure. The following table K-3 summarizes the results of the impact analysis for the sample water release plans. The figures in the table represent the sum of the economic impact, as measured by direct and indirect expenditures, and the recreation value generated by the lakes at the appropriate lake level. Each example assumes a different base scenario (option 2) as described in the table's notes. Consequently, no attempt should be made to compare one example with another since they are independent of each other.

The table illustrates the relative impacts of releasing supplemental discharges of 330 cfs from the system of reservoirs for three different starting conditions. Example 1 starts with each of the lakes at the bottom of their operating bands. Examples 2 and 3 have worse starting conditions with some of the lakes starting one foot below their operating band (Gull, Pine, Sandy in example 2; Leech, Winnibigoshish, Pokegama in example 3). The worse condition is manifested by the lower values for option 2. The figures under option 3 represent the remaining economic and recreation activity generated after supplemental releases of 330 cfs. Under example 1, the releases are made such that each lake experiences an equal drop in stage. Under examples 2 and 3, the releases are made from the lakes that can best afford the drop in stages. In example 2, the releases are drawn out of the bigger lakes (Leech, Winnibigoshish, Pokegama). They can achieve the 330 cfs supplemental release with a relatively small drop in stage. This is evident by the lower change value (457.1). In example 3, on the other hand, the supplemental releases are drawn out of the smaller lakes (Gull, Pine, Sandy; releases are not made from Winnibigoshish until Gull drops below minimum elevation). Larger drops in stage are required to furnish the necessary volume of water for the supplemental releases. This is reflected in the larger change value (1,214.0).

In conclusion, by using the process described above, the economic and recreation impacts of any drawdown scenario (option 3) given any starting base condition (option 2) can be analyzed. Other variables not included in this analysis will undoubtedly affect usage levels as well (for example,

Table K-3 Headwaters Low Flow Study – Summary of Economic and Recreation Impacts ($000)

Lake	Example 1			Example 2			Example 3		
	Option 2	Option 3	Change	Option 2	Option 3	Change	Option 2	Option 3	Change
Leech	3,541.0	3,289.1	251.9	3,541.0	3,289.1	251.9	1,837.1	1,837.1	0.0
Winnibigosh	1,185.7	1,015.6	170.1	1,185.7	1,015.6	170.1	332.9	163.3	169.6
Pokegama	457.4	422.3	35.1	457.4	422.3	35.1	206.5	206.5	0.0
Gull	2,256.7	2,080.2	176.5	1,093.7	1,093.7	0.0	2,256.7	1,612.9	643.8
Pine	1,856.4	1,774.3	82.1	833.2	833.2	0.0	1,856.4	1,774.3	82.1
Big Sandy	724.1	697.7	26.4	389.0	389.0	0.0	724.1	405.6	318.5
Total	10,021.3	9,279.2	742.1	7,500.0	7,042.9	457.1	7,213.7	5,999.7	1,214.0

Example 1 – All lakes at the bottom of their summer operating bands. Supplemental discharge is determined by equal drop in stage of all reservoirs.

Example 2 – Winnibigoshish, Leech, and Pokegema at bottom of summer bands. Sandy, Pine, and Gull are one foot below summer bands. Supplemental discharge is determined by equal drop in stage of Winnibigoshish Leech, and Pokegama. No supplemental releases from Sandy, Pine, and Gull.

Example 3 – Sandy, Pine, & Gull at bottom of summer bands. Winnibigoshish, Leech, & Pokegema are one foot below summer bands. Supplemental discharge is determined by equal drop in stage of Sandy, Pine, and Gull. No supplemental releases from Winnibigoshish, Leech, and Pokegama.

Option 2 – Evaporation plus minimum releases. This is the base condition from which supplemental releases commence. The numbers represent the economic and recreation activity generated at this lake level. For instance, in example 1, the Pine Lake water level under option 2 generates $1,856,400 in economic and recreation activity. In example 2, though, with the option 2 lake level one foot lower, Pine Lake only generates $833,200.

Option 3 – Evaporation plus minimum releases plus supplemental releases.

users' perceptions, negative media coverage, response of resort owners and riparian residents to mitigate effects of low lake levels). Because of this, the results of the analysis should be used only to compare relative impacts of alternative drawdown scenarios on a lake to lake basis. They should not be used as the definitive statement of expected economic and recreation impacts to the local economy attributed to an action by the Federal Government (i.e., reservoir drawdown).

APPENDIX L

EFFECTS OF LOW LAKE LEVELS

ON MISSISSIPPI RIVER HEADWATERS LAKES RESOURCES

EFFECTS ON LOW LAKE LEVELS ON MISSISSIPPI RIVER HEADWATERS LAKES RESOURCES

Introduction

1.0 The Mississippi River headwaters lakes are impounded natural lakes located in north central Minnesota. Lakes Winnibigoshish, Leech, Pokegama, Sandy, Pine River Dam at the Whitefish Chain of Lakes, and Gull, have dams that are operated by the St. Paul District, Corps of Engineers. The dams were originally constructed to provide low flow augmentation for navigation on the Mississippi River. Since construction of the Mississippi River 9-foot channel navigation project, the lakes have been operated to provide flood control, for low flow augmentation, to stabilize water levels for recreational use of the lakes, to manage fish and wildlife habitat, to reduce shoreline erosion and protect shoreline cultural resources, and to encourage production of wild rice.

1.1 Downstream water use demands have made low flow augmentation an increasingly important function of the headwaters lakes. Releases from the headwaters lakes to meet downstream needs must be balanced with the need for water remaining in the lakes to support headwaters lakes uses and resources.

1.2 The purpose of this report is to identify the effects of low lake levels on natural resources of the headwaters lakes. Sections 5.0 and 5.1 contain recommendations for additional information that would enhance the water control decision process for the project.

Description of Mississippi River Headwaters Lakes

<u>Location</u>

2.0 The headwaters lakes system is located in Aitkin, Beltrami, Cass, Crow Wing, Clearwater, Hubbard, St. Louis, Carlton, and Itaska Counties in north central Minnesota (figure L-1). Lakes Winnibigoshish and Pokegama are situated on the main stem of the Mississippi River. The other headwaters lakes flow into rivers tributary to the Mississippi River. Lake Winnibigoshish is the uppermost of the headwaters lakes operated by the

Corps of Engineers. Winnibigoshish Dam is 383 river miles upstream of St. Anthony Falls in Minneapolis, Minnesota.

Morphology

2.1 The headwaters lakes are impounded natural lakes of glacial origin. Dams raised the natural water surface on the lakes, inundating additional area. Table L-1 provides data on the physical characteristics of the headwaters lakes. Lake elevations and associated data are for normal summer pool elevations of the respective lakes. Data are from the Corps of Engineers reservoir regulation manuals, Bemidji State University (1973), Megard (1980), and Wilcox (1979).

System Operation During Low Flow Periods

2.2 The headwaters lakes are operated as a system by the Corps of Engineers, according to Congressional directive specified in 33 CFS 207.340 (d) and by operating plan contained in the project water regulation manuals. The plan for system operation contains a number of considerations for low flow operation of the project, including an informal agreement with the Minnesota Department of Natural Resources (MDNR) for desirable low flow releases to meet instream flow needs.

2.3 Minimum average annual releases, as far as can practically be maintained, are specified by 33 CFS 207.340(d) to be as shown in the first column of table L-2.

2.4 So far as is practical, the lakes are to be maintained above certain minimum elevations shown in the right-hand column of table L-2, according to 33 CFR 207.340(d). Any releases from the headwaters lakes when they are below these elevations would require direction of the Chief of Engineers. Surplus water in storage above these minimum elevations, not required for navigation, may be discharged at the discretion of the District Engineer to produce the greatest public benefit and minimum of injury to affected interests. Headwaters lake elevations have not fallen below these elevations since impoundment.

2.5 In addition to Federal law, the St. Paul District has an informal agreement with the MDNR, based on MDNR recommendations, to make minimum

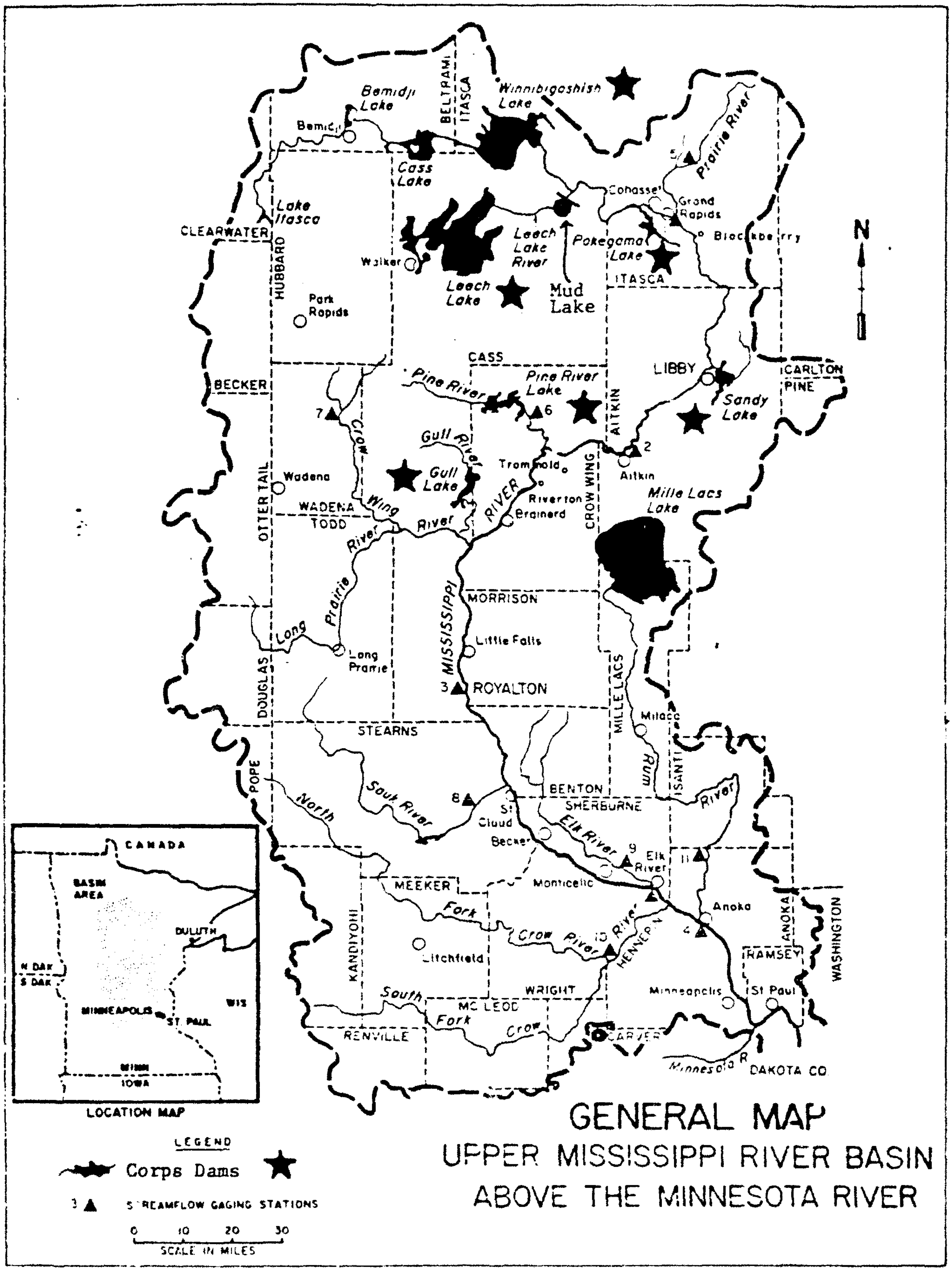


Figure L-1. Location of Mississippi River headwaters lakes.

Table L-1. Physical characteristics of Mississippi River headwaters Lakes

Lake	Elevation (ft NGVD)	Surface Area (x 1000 acres)	Volume (x 1000 acre-ft)	Storage (x 1000 acre-ft)	Watershed (sq. miles)	Shoreline (miles)	Max. Depth (ft)	Mean Depth (ft)
Winnibigoshish	1298.2	68.0		700	1442	35	78	
Leech	1294.7	117.0	1754.8	580	1163	182	140	16
Pokegama	1273.4	16.8		97.8	3265	51	110	
Sandy	1216.3	9.4	178.2	60.8	421	56.5	84	17
Pine	1229.3	13.6		101.3	562	112		
Gull	1194.0	13.1		61.0	287	35.6	87	

Table L-2. Low flow period releases and elevations for the Mississippi River headwaters lakes.

Lake	Minimum Average Annual Release (cfs)	Minimum Release (cfs)	Trigger Elevation (a)	1/2 Minimum Release (cfs)	Trigger Elevation (b)
Winnibigoshish	150	100	1297.94	50	1294.94
Leech	70	100	1294.50	50	1292.7
Pokegama (c)	200	200	1273.17	100	1270.42
Sandy	80	20	1216.06	10	1214.31
Pine	90	30	1229.07	15	1225.32
Gull	30	20	1193.75	10	1192.75

a - bottom of desirable summer range of lake surface elevation
b - Congressionally-mandated minimum lake elevation
c - releases from Pokegama are limited to the sum of discharges from Winnibigoshish and Leech Lakes

flow releases for instream flow needs during low flow periods. The agreement calls for minimum releases to be initiated when lake stages fall to the bottom of the desirable summer range of elevation, and to be reduced by half when the Congressionally-mandated minimum lake elevations are attained (table L-2). Releases from Pokegama Lake are limited to the sum of discharges from Leech and Winnibigoshish Lakes upstream. The combined minimum release from the six headwaters lakes is 270 cfs. The contingency for reducing minimum releases by half in the event of extreme low lake stages has not been necessary to date.

2.6 Water is released from the headwaters lakes starting after Labor Day to draw down lake levels to accommodate expected spring runoff. These winter drawdowns are conducted as necessary to attain ordinary minimum elevations by March 1. During dry conditions, the lakes are drawn down only as conditions warrant.

Resources Affected by Low Lake States

3.0 Natural resources of the headwaters lakes that are affected by low lake stages are: water quality, lake substrate, aquatic plants, wild rice, fish, aquatic macroinvertebrates, fish-eating birds, waterfowl, and furbearers. The morphology of each lake (the relationship between lake stage and water surface area), the distribution of resources within each lake, and the seasonal timing, duration, and elevation of low lake stages are factors which greatly affect the degree of impact that is imposed by low lake stage. The mechanisms of impact by low lake stages on natural resources of the headwaters lakes are discussed below.

<u>Effects of Low Lake Stage on Water Quality</u>

3.1 Water quality in the headwaters lakes is good. The lakes are mostly mesotrophic in character, with sufficient availability of plant nutrients to support abundant aquatic life without nuisance blue-green algae blooms. All the lakes except for the shallow, wind-swept Winnibigoshish stratify during the summer. Shallow portions of Leech Lake also remain mixed by wind action. Water clarity is generally good, and oxygen production by algae is sufficient to maintain dissolved oxygen well above 5 mg/l in the epilimnion (the warmer surface layer in a thermally stratified lake, see figure L-2).

Summary Stratification

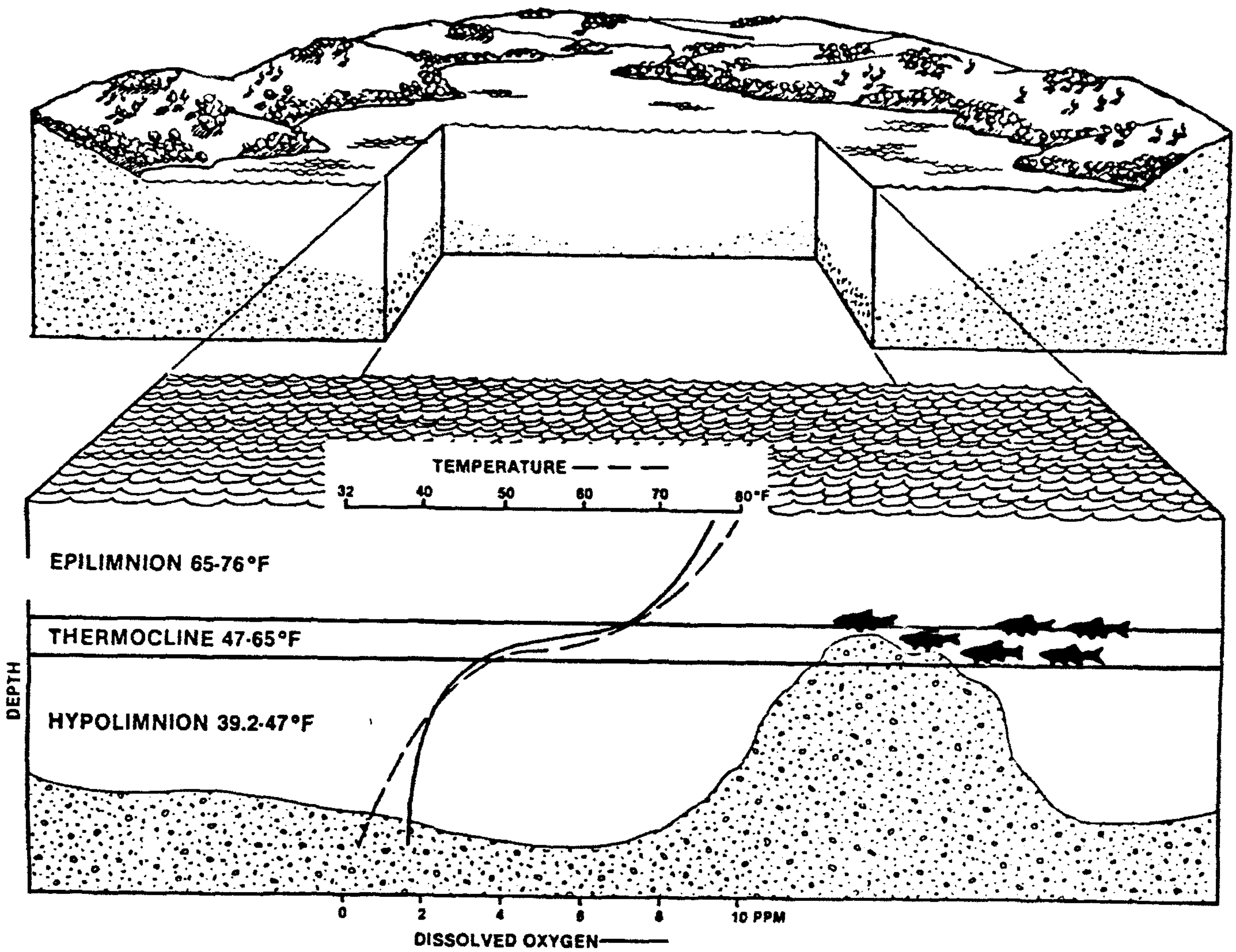


Figure L-2. Lake stratification.

graphics courtesy of University of Wisconsin - Extension

Summerkill of Fish

3.2 One potential water quality problem in the headwaters lakes associated with low lake stages is a physical/chemical condition that can affect the volume of habitat available for some fish species. Cisco (Coregonus artedii), lake whitefish (Coregonus clupeaformis) and white suckers (Catastomus commersoni) are fish species that are vulnerable to a temperature and dissolved oxygen-related summerkill phenomenon that occurs in many northern lakes.

3.3 Cisco are members of the whitefish family, and are also known as tullibee or lake herring. Cisco seek the lake's deepest level which provides cool, oxygen-abundant water as the surface waters warm. As the summer progresses and oxygen is depleted from the hypolimnion, the cisco are forced upward into the warmer temperatures of the thermocline. Late summer is a critical period for cisco, when they are forced by lack of sufficient oxygen upward into water that is warmer than they can tolerate (Becker 1983). White suckers, and to a lesser extent, lake whitefish seem to be vulnerable to the same conditions as cisco. Drought conditions, with maximal surface water temperatures, and losses of surface water by release from the dams and by evaporation, can exacerbate the conditions that can lead to summerkill of fish. There has been no water quality monitoring concurrent with summerkill of fish in the headwaters lakes that would allow analysis of the relationship between low lake levels and the summerkill phenomenon.

3.4 Summerkill has occurred during extended hot periods in Winnibigoshish, Gull, and Leech Lakes. The summerkill phenomenon in Lake Winnibigoshish appears to be related to periods of extended hot, calm weather which produce elevated water temperatures near the surface, and oxygen depletion in deeper water that occurs due to temporary stratification. The summerkill on Lake Winnibigoshish appears to be related more to temporary stratification of the normally wind-mixed lake than to any water level-related mechanism (D. Holmbeck pers. comm. 1989).

3.5 Lake whitefish are closely related to cisco. They are usually less abundant than cisco and use deeper water habitat. Lake whitefish are cultured, and stocked for later commercial harvest in Leech Lake and other

lakes by the Leech Lake Chippewa Department of Natural Resources. The Leech Lake DNR and the MDNR have noted summerkill of lake whitefish, but not to the extent that cisco and white suckers are affected, and the summerkills of lake whitefish have not measurably affected the commercial fishery (J. Ringley, D. Holmbeck pers. comm. 1989).

Physical Disturbance of Lake Substrate

3.6 Sediment in the headwaters lakes near-shore areas is a mixture of mineral particles, inorganic matter of biogenic origin, and organic matter in various stages of decomposition. Wind-driven wave action exerts considerable force on the lake bottom in shallow areas, suspending fine materials and focusing them toward the deeper portions of the lake basins. Fine sediment accumulations occur in the near-shore zone of the headwaters lakes, along shorelines that are subject to significant wave action, is scoured free of fine-grained sediment to a depth of approximately 3 to 5 feet below the historic open-water season low lake elevation. Below this elevation, accumulation of fine-grained sediment occurs continuously.

3.7 When lake levels fall below recent historic lows, wave energy is exerted on lake substrate that is normally in a depositional zone for fine-grained sediment. Sediment is resuspended, and a band of lake substrate at lower elevation is scoured free of fine-grained sediment. When this process occurs gradually, water quality is not greatly impaired by sediment resuspended by wave action. Rapid drawdown of lake elevation to below recent historic levels, however, could result in considerable resuspension of fine material from the lake bed by wave action.

Mobilization of In-Place Pollutants

3.8 The headwaters lakes are relatively free of contaminants. Mercury is present in the lakes, originating from the geology of the watershed and from aerial deposition. Mercury is absorbed to fine-grained sediment particles, making the fine sediment a sink for mercury in the lakes. When lake levels fall to below recent historic low elevations, fine-grained sediment is physically disturbed by wave action, and interstitial water and material is removed from sediment deposits as lake levels decline. This process can result in more mercury in the water column, and in forms that are available for uptake by the biota. The effect of sediment desiccation

and oxidation on the microbial methylation of mercury and the resulting availab ity of toxic forms of mercury upon refilling of the lakes is unclear. Mercury in fish is not a major problem in any of the headwaters lakes at this time. Normal operation of the headwaters lakes probably does not have a major effect on the availability of mercury (D. Helwig pers. comm. 1989). Fish consumption advisories recommending not more than one meal per week of larger northern pike and walleye have been issued by the State because of mercury contamination of fish in Leech, Winnibigoshish, Sandy, and Gull Lakes.

Effects of Low Lake Stage on Aquatic Plants

3.9 The headwaters lakes support a diverse assemblage of submersed and emergent aquatic plants (wild rice is discussed in the next section). The aquatic plant beds occur in shallow portions of the headwaters lakes that have stable substrate and are not subject to strong wave action. Extremely low lake elevations below recent historic minimums desiccate plant beds. Low lake levels that occur throughout the growing season allow growth of aquatic plants at lower elevations on the lake bed where they are limited by light penetration in normal years. Desiccation of aquatic plants during the winter kills the overwintering vegetative stage of most species, resulting in much reduced abundance of plants the following year. Desiccation of the lake bed by low lake levels can have a positive effect on many species of emergent aquatic plants by causing germination of seeds and by oxidation of sediments. Emergent vegetation in setland areas that are connected to headwaters lakes can be stimulated by an occasional low-water year through germination seeds and by the release of nutrients that accompanies the oxydation and drying of sediments.

Effects of Low Lake Stage on Wild Rice

3.10 Wild rice grows in extensive stands in Leech, Winnibigoshish, and Sandy Lakes. Wild rice is a nutritional, cultural, and economic mainstay of the Leech Lake and Mille Lacs Bands of Chippewa. Leech Lake supports approximately 3,700 acres, Winnibigoshish Lake supports 2,700 acres, and Sandy Lake supports about 1,000 acres of wild rice beds. In a good year, 150 to 300 pounds of wild rice can be harvested per acre.

3.11 An annual grass that grows in shallow water, wild rice is affected by declining water levels in a number of ways. Low lake levels can subject the floating-leaf stage of the immature plant to more wave action and uprooting. Once the plant is emergent, declining lake levels reduce the support provided by the water to the stalk, resulting in more lodging of the plant tops and stem breakage. Declining lake levels during flowering and seed development may stress the plants, also resulting in reduced yield of rice. If water levels decline sufficiently, rice seed on the lake bed becomes dried out, reducing its viability (Leech Lake Reservation, Division of Resources Management 1989).

3.12 The primary effect of low lake levels on the rice harvest is by limiting boat access into the wild rice beds. Wild rice is traditionally harvested from canoes. A loaded canoe with two individuals requires approximately 6 inches of water. Declining lake levels render increasing areas of wild rice beds inaccessible for harvest.

3.13 A survey of wild rice beds in Leech, Winnibigoshish, and Sandy Lakes was conducted in the summer of 1989 by the Leech Lake and Mille Lacs Bands and the Corps of Engineers. Lake bed elevation in each major wild rice bed was measured. This data, along with satellite imagery of the headwaters lakes, is currently being entered into the St. Paul District computer Geographic Information Systems (GIS). The location and aerial extent of the rice beds, along with contour elevations of lake bottom in the rice beds, will be mapped. It will be possible to calculate acreage of wild rice beds at different elevations. Acquisition of future satellite imagery of the headwaters lakes will allow monitoring of change in the location and extent of the wild rice beds.

<u>Effects of Low Lake Stage on Fishery</u>

3.14 Low lake stages in the summer, fall, and winter have relatively little effect on fish in the headwaters lakes. Sufficient volume of habitat remains even at extremely low lake elevations to prevent stranding, overcrowding, or poor water quality. Some loss of shallow vegetated habitat occurs, which is important to young-of-year fish. Low lake levels in the spring limit habitat available for spawning northern pike and

walleye (Wilcox 1979). Aside from the summerkills (described above), no particular problem with fish or fish habitat has been associated with low summer, fall, and winter stages on the headwaters lakes.

3.15 Commercial harvesting of baitfish by the Leech Lake Band on Lake Winnibigoshish is hampered by low lake levels.

Effects of Low Lake Stages on Furbearers

3.16 Beaver, mink, otter, and muskrat are all furbearers that inhabit the headwaters lakes and make use of dens at the water's edge. Declining lake levels expose den entrances and result in increasing distances between dens and the water's edge, and lack of under-ice access, subjecting the animals to increased predation. Furbearers inhabiting the shores of the headwaters lakes are already subjected to declining winter water levels by the routine drawdowns. These declining water levels may limit the abundance of furbearers around the headwaters lakes.

Effects of Low Lake Stages on Fish-Eating Birds

3.17 Bald eagles, herons, cormorants, loons, kingfishers, mergansers, gulls, and terns have creased area of shallow aquatic habitat for foraging during low lake stages. Young-of-year fish forced out of aquatic macrophyte beds may provide easier prey for birds.

Effects of Low Lake Stages on Waterfowl

3.18 Waterfowl are affected by low lake stages by desiccation of shallow aquatic and wetland habitat, and by increased distance from nests to the water.

Summary

4.0 Low stages on the headwaters lakes during the summer, fall, and winter that can be expected to occur during future drought conditions have relatively minor effects on water quality, fish, and wildlife. Lake levels lower than recent historic minimums scour fine-grained lake substrate. Low lake stages that could occur in the spring during an extended drought or due to deliberate releases would limit spawning of walleye and northern pike. Winter lake levels below recent minima would kill exposed

macrophytes, limiting abundance of aquatic plants for at least one year. Declining lake levels below normal summer elevations limit production of wild rice and access into wild rice beds for harvest. Occasional low water years can have a positive effect on growth of emergent wetland vegetation.

Recommendations

Computer Geographic Information System Mapping of Headwaters Resources

5.0 The St. Paul District, Corps of Engineers should make use of it's computer GIS system to inventory headwaters lake resources. Satellite imagery of the are has been acquired. We recommend that the satellite imagery data, MDNR bathymetric survey maps of the lakes, and wild rice survey data obtained during the summer of 1989 be entered on the GIS system. Satellite imagery should be acquired in future years to monitor the location and extent of wild rice beds. Products that should be prepared using the GIS system are:

- Maps of Lakes Winnibigoshish, Sandy, and leech showing location and extent of wild rice beds.
- Maps of lake bed elevation in wild rice beds.
- Acreage of wild rice beds on each lake with 6 inches or more of water at different water surface elevations.
- Bathymetric maps of each lake.
- Lake acreage at different water surface elevations.

These products should be provided to the Leech Lake and Mille Lacs Bands and to the MDNR.

Water Quality Monitoring

5.1 The St. Paul District should expand its water quality monitoring program to include each of the headwaters lakes. Basic limnological water quality monitoring should be conducted on a weekly schedule during the open water season. Profiles of water temperature and dissolved oxygen within each lake and subbasin would allow evaluation of the effects of declining lake levels on water quality and project operation effects on trust resources. The District should cooperatively identify specific information needs to enhance water control of the project lakes. Information needs

should also include cultural resources and the cultural significance of natural resources of the Chippewa people.

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APPENDIX M

MDNR POLICIES AND APPLICABLE MINNESOTA STATUTES

MINNESOTA'S WATER APPROPRIATION PROGRAM

Minnesota's water appropriation law was first enacted in 1937 (Re: Minnesota Statutes Chapter 105) as a result of the drought of the 1930's. The Legislature sought, by the original act, to establish a water policy for the state and a permit system to regulate water users.

The most important changes to the original law include requirements for submitting annual water use reports, the repeal of the exemption for so called "grandfather appropriators", the establishment of a priority system for water use, and the requirement to establish rules governing the allocation of waters which were adopted in August of 1980.

Minnesota Rules Part 6115.0620 requires that a permit be obtained for appropriation of water in excess of 10,000 gallons per day or one million gallons per year. Applications to appropriate water are evaluated to determine the effects of the proposal on the environment and other high priority water users.

In 1973, the Legislature established five priority classes of water use. After the 1988 drought the original priorities were modified by the 1989 Legislature to include certain power production requirements under first priority water uses. This change is intended to provide essential power requirements during a widespread drought when other power suppliers within a grid may be having difficulty meeting demand. The current water use priorities as amended in 1989 are:

> First Priority. Domestic water supply, excluding industrial and commercial uses of municipal water supply, and use for power production that meets contingency planning requirements.
>
> Second Priority. A use of water that involves consumption of less than 10,000 gallons per day.
>
> Third Priority. Agricultural irrigation and processing of agricultural products.
>
> Fourth Priority. Power production in excess of the use provided for in the contingency plan requirements.
>
> Fifth Priority. All other uses, involving consumption in excess of 10,000 gallons per day, including non-essential uses of public water supplies.

These priorities of water use become important during periods of limited water supplies and competing demands. While environmental protection is not given in the priority system it is provided for in Minnesota Statutes and Rules by the establishement of resource limitations below which no appropriation can occur.

When is a DNR permit needed?
A DNR water appropriation permit is needed to appropriate or use waters of the state for any domestic use serving more than 25 persons and for any other use which exceeds 10,000 gallons in any one day, or 1,000,000 gallons in a year.

What priorities are set for water use?
If there isn't enough water for everyone, Minnesota law sets general priorities for which users can appropriate waters of the state. These priorities, from highest priority to lowest priority, are as follows:

1. Domestic water supplies and power production with contingency plans;
2. Uses of water consuming less than 10,000 gallons per day;
3. Agricultural irrigation and processing of agricultural products;
4. Power production without contingency plans;
5. All other uses.

What limitations are put on irrigation from groundwater?
Except in areas where groundwater availability is already known, the permit applicant must run a pumping test at their own expense. The permit will be issued if the test shows there is enough water both for the applicant and for existing wells in the vicinity. If the pumping draws-down water below the reach of nearby domestic wells, the applicant must work something out with those well-owners before a permit will be issued.

What limitations are put on irrigation from surface water?
Minnesota law sets water use limits for waterbasins and watercourses and also discourages taking water from waterbasins less than 500 acres in area. On any waterbasin, the total of all withdrawals cannot be more than one-half acre foot per acre per year (6 inches of water taken off the surface of the waterbasin). The DNR can also establish minimum protection elevations for waterbasins and protected low flows for watercourses.

REGULATION OF PROTECTED WATERS AND WETLANDS:

What are protected waters and wetlands?
Protected Waters are all waterbasins and watercourses that meet the criteria set forth in Minnesota Statutes Section 105.37, subd. 14 and are designated on the DNR's Protected Waters and Wetlands Inventory maps. Protected Wetlands include all types 3, 4 and 5 wetlands (as defined in U.S. Fish and Wildlife Service Circular No.39, 1971 ed.) which are 10 or more acres in size in rural areas or 2 1/2 or more acres in size within cities and are designated on the DNR's Protected Waters and Wetlands Inventory.

Editor's Note: This information is provided as background to partially explain the state's assertion of at least partial authority for water control of the Headwaters Lakes Project. However, the District Engineer cannot recognize concurrent authority with the state until Congress authorizes such authority. 2437

Editor's Note: The Minnesota Legislature asserts that the state has rights to control of project waters, but Congress has not provided such concurrent authority to the state.

110.47 HEADWATER LAKES OF MISSISSIPPI, REASON FOR CONTROL.

It is the considered judgment of the legislature of the state of Minnesota that the regulation, control, and utilization of waters in the headwater lakes in the Mississippi river, including Leech Lake, Winnibigoshish Lake, Pokegama Lake, Pine river, (the Whitefish chain), Sandy Lake and Gull Lake are of tremendous economic importance and value to the state of Minnesota. It is further the considered judgment of the legislature of Minnesota that the utility of these lakes in aid of navigation has been very greatly diminished since the time of the establishment of the reservoirs, and that the economic values in utilization of these waters for state purposes has increased tremendously. These factors require the assertion on the part of the state of Minnesota of its rights to utilization and control of these water areas.

History: *1961 c 459 s 1*

(1) **110.48 JOINT FEDERAL-STATE CONTROL.**

The commissioner of natural resources is authorized and directed to enter into cooperative agreements with the United States of America acting through the department of the army for the joint control and regulation of these reservoirs within the principles hereinafter prescribed so as to effectuate control of the water elevations and the water discharges from these lakes in the interests of the state of Minnesota, subject only to any paramount need of waters from these sources in aid of substantial navigation requirements, and subject further to any substantial requirement of providing necessary flood control storage capacity as determined by the corps of army engineers.

History: *1961 c 459 s 2; 1969 c 1129 art 3 s 1*

110.49 PLAN FOR DAM OPERATION.

The commissioner of natural resources is hereby authorized and directed to formulate a plan for the operation of the dams controlling each of the reservoirs hereinabove named which will:

(a) Seek to establish the water elevation on each of the lakes at the most desirable height, and to stabilize the stages at that point, insofar as practicable, during the recreational season in Minnesota;

(b) Give due consideration to providing for any reasonable fluctuations when desirable for the production of wild rice in the wild rice producing areas of these lakes;

(c) Take into account the elevations most desirable for the production and maintenance of wild life resources;

(d) Give due consideration to needs of water for recreation, agriculture, forestry, game and fish, industry, municipal water supply and sewage disposal, power generation, and other purposes in the Mississippi river headwaters and downstream;

(1) While the Minnesota Legislature authorized the Commissioner of Natural Resources to enter an agreement for joint Federal-State control of the Headwaters Lakes Project, Congress has not authorized concurrent water control authority for the project. Unless and until Congress authorized concurrent authority to the state, then the Secretary of the Army has sole authority for project water control.

(e) Establish stages at which the water shall be maintained so far as practicable, but basically recognizing the following minimum stages in reference to present zeros on the respective government gauges:

Leech Lake 0.0

Winnibigoshish Lake 6.0

Pokegama Lake 6.0

Sandy Lake 7.0

Pine River 9.0

Gull Lake 5.0

(f) Prescribe maximum discharges at any time the elevations fall below such stages;

(g) Prescribe maximum elevations and amounts of discharge from each lake so as best to stabilize and effectuate the desired stages. Insofar as practicable, the following maximum lake stages shall not be exceeded:

Leech Lake 3.5

Winnibigoshish Lake 12.0

Pokegama Lake 12.0

Sandy Lake 11.0

Pine River 14.0

Gull Lake 7.0

History: *1961 c 459 s 3; 1969 c 1129 art 3 s 1*

110.50 POTENTIALS COMPREHENDED BY PLAN.

The plan devised by the commissioner shall comprehend the following potentials:

(a) The necessity for changing discharges to meet any emergencies resulting from unexpected or abnormal inflows;

(b) The possibility of overriding requirements of the federal government for substantial discharges to meet reasonable and substantial navigation requirements;

(c) The overriding authority and needs as prescribed by the army engineers in discharging their functions of requiring additional storage capacity for flood control purposes.

History: *1961 c 459 s 4*

110.51 NOTICE OF PLAN; HEARING.

Before the plan of operation for any headwater lake is put into effect, the commissioner shall publish a notice of hearing upon said plan for two weeks in a newspaper in each county in which the water areas to be affected lie. The hearing shall be conducted by the commissioner or a duly appointed referee. All interested parties shall have an opportunity to be heard, shall testify under oath, and shall be subject to cross examination by any adverse parties, and by the attorney general, or the attorney general's representative, who shall represent the commissioner at said hearing. The hearing will not be governed by legal rules of evidence, but the findings of fact and orders, to be made and formulated by the commissioner, shall be predicated only upon relevant, material, and competent evidence. The findings of fact and orders incorporating the plan determined upon by the commissioner shall be published for two weeks in the same manner as the notice of hearing was published.

History: *1961 c 459 s 5; 1986 c 444*

110.52 APPEAL.

Any riparian land owner or water user aggrieved by such findings shall have the right to appeal within 30 days of the completion of publication to the district court of any county in which the regulated water lies, which appeal shall be determined by the

court on the record made before the commissioner of natural resources. Issues on any such appeal shall be the legal rights of the parties and the further question as to whether the findings of the commissioner are reasonably supported by the evidence adduced at the hearing.

History: *1961 c 459 s 6; 1969 c 1129 art 3 s 1*

110.53 MODIFICATIONS.

It is recognized that experience may require changes in the elevations sought to be maintained on each of the headwater lakes. Consequently, once a plan has been put into effect, the commissioner is authorized to modify the stages sought to be maintained by modifying the plan with respect to any of the lakes involved to the extent of one foot in elevation according to the zeros of the present government gauges without the necessity of further or additional hearings; provided that in no event shall any departure from the elevation target be made so as to reduce any proposed stages below the minimums prescribed by section 110.49, clause (e) during the recreational season. Any modification of the plan established subsequent to the hearings herein provided which departs by more than one foot in elevation shall be placed into effect only upon further hearing proceeding upon the same formalities as the hearing hereinabove prescribed.

History: *1961 c 459 s 7; 1976 c 239 s 21; 1986 c 444*

ARTICLE 4

WATER CONSERVATION

Section 1. Minnesota Statutes 1988, section 105.41, subdivision 1, is amended to read:

Subdivision 1. **COMMISSIONER'S PERMISSION.** (a) It is unlawful for the state, any person, partnership, or association, private or public corporation, county, municipality, or other political subdivision of the state to appropriate or use any waters of the state, surface or underground, without the written permit of the commissioner. This section does not apply to the use of water for domestic purposes serving less than 25 persons. The commissioner shall set up a statewide training program to provide training in the conduct of pumping tests and data acquisition programs.

(b) A permit may not be issued under this section unless the permit is consistent with state, regional, and local water and related land resources management plans.

(c) The commissioner may not modify or restrict the amount of appropriation from a groundwater source authorized in a permit issued for agricultural irrigation under section 105.44, subdivision 8, between May 1 and October 1 of any year, unless the commissioner determines the authorized amount of appropriation endangers a domestic water supply.

Sec. 2. Minnesota Statutes 1988, section 105.41, subdivision 1a, is amended to read:

Subd. 1a. **WATER ALLOCATION ~~RULES,~~ PRIORITIES.** (a) The commissioner shall ~~submit to the legislature by January 1, 1975, for its approval, proposed~~ adopt rules ~~governing the~~ for allocation of waters ~~among potential water users.~~ ~~These rules must be~~ based on the following priorities for the consumptive appropriation and use of water:

(1) first priority: domestic water supply~~;~~ excluding industrial and commercial uses of municipal water supply~~.~~, and use for power production that meets the contingency planning provisions of section 105.417, subdivision 5;

(2) second priority: ~~any~~ a use of water that involves consumption of less than 10,000 gallons of water ~~a~~ per day~~.~~ ~~In this section "consumption" means water withdrawn from a supply that is lost for immediate further use in the area.~~;

(3) third priority: agricultural irrigation and processing of agricultural products, involving consumption in excess of 10,000 gallons ~~a~~ per day~~;~~ ~~and processing of agricultural products.~~;

(4) fourth priority: power production~~, involving consumption in excess of 10,000 gallons a day.~~ in excess of the use provided for in the contingency plan developed under section 105.417, subdivision 5; and

New language is indicated by underline, deletions by strikeout.

(5) fifth priority: ~~other~~ uses, other than agricultural irrigation, processing of agricultural products, and power production, involving consumption in excess of 10,000 gallons ~~a~~ per day and nonessential uses of public water supplies as defined in section 105.518, subdivision 1.

(b) For the purposes of this section, "consumption" shall mean water withdrawn from a supply which is lost for immediate further use in the area.

(c) Appropriation and use of surface water from streams during periods of flood flows and high water levels must be encouraged subject to consideration of the purposes for use, quantities to be used, and the number of persons appropriating water.

(d) Appropriation and use of surface water from lakes of less than 500 acres in surface area must be discouraged.

(e) The treatment and reuse of water from nonconsumptive uses shall be encouraged.

(f) Diversions of water from the state for use in other states or regions of the United States or Canada must be discouraged.

~~No permit may be issued under this section unless it is consistent with state, regional, and local water and related land resources management plans, if regional and local plans are consistent with statewide plans. The commissioner must not modify or restrict the amount of appropriation from a groundwater source authorized in a permit issued under section 105.44, subdivision 8, between May 1 and October 1 of any year, unless the commissioner determines the authorized amount of appropriation endangers any domestic water supply.~~

Sec. 3. Minnesota Statutes 1988, section 105.41, subdivision 1b, is amended to read:

Subd. 1b. **USE LESS THAN MINIMUM.** ~~No~~ Except for local permits under section 473.877, subdivision 1, a permit is not required for the appropriation and use of less than a minimum amount to be established by the commissioner by rule. Permits for more than the minimum amount but less than an intermediate amount to be specified by the commissioner by rule must be processed and approved at the municipal, county, or regional level based on rules to be established by the commissioner by January 1, 1977. The rules must include provisions for reporting to the commissioner the amounts of water appropriated under local permits.

Sec. 4. Minnesota Statutes 1988, section 105.41, is amended by adding a subdivision to read:

Subd. 1c. **CERTAIN COOLING SYSTEM PERMITS PROHIBITED.** (a) The commissioner may not issue a water use permit from a groundwater source for a once-through cooling system using in excess of five million gallons annually.

(b) For purposes of this subdivision, a once-through cooling system means a cooling or heating system for human comfort that draws a continuous stream of water from a groundwater source to remove or add heat for cooling, heating, or refrigeration.

Sec. 5. Minnesota Statutes 1988, section 105.41, subdivision 5, is amended to read:

Subd. 5. **RECORDS REQUIRED.** Records of the amount of water appropriated or used must be kept for each installation. The readings and the total amount of water appropriated must be reported annually to the commissioner of natural resources on or before February 15 of the following year upon forms to be supplied by the commissioner.

The records must be submitted with an annual water appropriation processing fee in the amount established in accordance with the following schedule of fees for each water appropriation permit in force at any time during the year~~: (1) irrigation permits, $15 for the first permitted 160 acres or part of 160 acres, and $25 for each additional permitted 160 acres or part of 160 acres; (2) for nonirrigation permits, $5 for each ten million gallons or portion of that amount permitted each year. However, the fee must not exceed a total of $500 per permit~~.

Subd. 5a. **WATER USE PROCESSING FEE.** (a) Except as provided in paragraph (b), a water use processing fee not to exceed $2,000 must be prescribed by the commissioner in accordance with the following schedule of fees for each water use permit in force at any time during the year:

(1) 0.05 cent per 1,000 gallons for the first 50 million gallons per year, and

(2) 0.1 cents per 1,000 gallons for the amounts greater than 50 million gallons per year.

(b) For once-through cooling systems as defined in subdivision 1c, a water use processing fee must be prescribed by the commissioner in accordance with the following schedule of fees for each water use permit in force at any time during the year:

(1) 5.0 cents per 1,000 gallons until December 31, 1991;

(2) 10.0 cents for 1,000 gallons from January 1, 1992, until December 31, 1996; and

(3) 15.0 cents per 1,000 gallons after January 1, 1997.

(c) The fee is payable ~~regardless of~~ based on the amount of water ~~appropriated~~ permitted during the year and in no case may the fee be less than $25.

(d) Failure to pay the fee is sufficient cause for revoking a permit. ~~No fee may be imposed on any state agency, as defined in section 16B.01, or federal governmental agency holding a water appropriation permit.~~

New language is indicated by underline, deletions by ~~strikeout~~.

Sec. 6. Minnesota Statutes 1988, section 105.418, is amended to read:

105.418 CONSERVATION OF PUBLIC WATER SUPPLIES.

(a) During periods of critical water deficiency as determined by the governor and declared by executive order of the governor, public water supply authorities appropriating water shall adopt and enforce restrictions consistent with rules adopted by the commissioner of natural resources within their areas of jurisdiction. The restrictions must limit lawn sprinkling, car washing, golf course and park irrigation, and other nonessential uses and have appropriate penalties for failure to comply with the restrictions.

(b) The commissioner may adopt ~~emergency~~ rules ~~according to sections 14.29 to 14.36~~ relating to matters covered by this section ~~during the year 1977~~.

(c) Disregard of critical water deficiency orders, even though total appropriation remains less than that permitted, is adequate grounds for immediate modification of ~~any~~ a public water supply authority's ~~appropriator's~~ water use permit.

Sec. 7. Minnesota Statutes 1988, section 473.877, is amended by adding a subdivision to read:

Subd. 4. **APPROPRIATIONS FROM SMALL WATERCOURSES.** (a) This subdivision applies in Hennepin and Ramsey counties to the following public waters:

(1) a public water basin or wetland wholly within the county that is less than 500 acres; or

(2) a protected watercourse that has a drainage area of less than 50 square miles.

(b) An appropriation of water that is below the minimum established in section 105.41, subdivision 1b, for a nonessential use, as defined under section 105.418, is prohibited unless a permit is obtained from the watershed district or watershed management organization having jurisdiction over the public water basin, wetland, or watercourse. The watershed district or watershed management organization may impose a fee to cover the cost of issuing the permit. This subdivision must be enforced by the home rule charter or statutory city where the appropriation occurs. Violation of this subdivision is a petty misdemeanor, except that a second violation within a year is a misdemeanor. Affected cities shall mail notice of this law to affected riparian landowners.

Sec. 8. CONSUMPTIVE WATER USE STUDY.

The commissioner of natural resources shall conduct a study of consumptive water use and its impact on existing aquifers. The commissioner shall review methods of reducing consumptive water use, including the conversion of once-through cooling systems to alternative systems. The commissioner shall report to the legislative water commission by February 15, 1990, the commissioner's recommendations for alternatives to the once-through cooling systems.

New language is indicated by underline, deletions by ~~strikeout~~.

including the environmental and economic implications of the alternatives. The recommendations must include: options for converting once-through cooling systems; a time schedule for phasing out existing systems; recommended technologies to be used to accomplish the conversion; recommendations for a fee structure that will make once-through cooling systems and conventional systems equal in operating costs; recommendations on the use of deep aquifers for once-through cooling; recommendations on authorizing systems of better efficiency; and advisability of systems that recharge aquifers.

ARTICLE 5

PESTICIDE AMENDMENTS

Section 1. Minnesota Statutes 1988, section 18B.01, subdivision 5, is amended to read:

Subd. 5. **COMMERCIAL APPLICATOR.** "Commercial applicator" means a person who has or is required to have a commercial applicator license.

Sec. 2. Minnesota Statutes 1988, section 18B.01, is amended by adding a subdivision to read:

Subd. 4a. **COLLECTION SITE.** "Collection site" means a permanent or temporary designated location with scheduled hours for authorized collection where pesticide end users may bring their waste pesticides.

Sec. 3. Minnesota Statutes 1988, section 18B.01, is amended by adding a subdivision to read:

Subd. 6a. **CONTAINER.** "Container" means a portable device in which a material is stored, transported, treated, disposed of, or otherwise handled.

Sec. 4. Minnesota Statutes 1988, section 18B.01, is amended by adding a subdivision to read:

Subd. 6b. **CORRECTIVE ACTION.** "Corrective action" means an action taken to minimize, eliminate, or clean up an incident.

Sec. 5. Minnesota Statutes 1988, section 18B.01, subdivision 12, is amended to read:

Subd. 12. **INCIDENT.** "Incident" means a flood, fire, tornado, transportation accident, storage container rupture, ~~portable container rupture,~~ leak, spill, emission discharge, escape, disposal, or other event that releases or immediately threatens to release a pesticide accidentally or otherwise into the environment, and may cause unreasonable adverse effects on the environment. "Incident" does not include ~~the lawful use or intentional~~ a release ~~of a~~ from normal use of a pesticide or practice in accordance with ~~its approved labeling~~ law.

105.41 APPROPRIATION AND USE OF WATERS.

Subdivision 1. **Commissioner's permission.** It is unlawful for the state, any person, partnership, or association, private or public corporation, county, municipality, or other political subdivision of the state to appropriate or use any waters of the state, surface or underground, without the written permit of the commissioner. This section does not apply to the use of water for domestic purposes serving less than 25 persons. The commissioner shall set up a statewide training program to provide training in the conduct of pumping tests and data acquisition programs.

Subd. 1a. **Water allocation rules, priorities.** The commissioner shall submit to the legislature by January 1, 1975, for its approval, proposed rules governing the allocation of waters among potential water users. These rules must be based on the following priorities for appropriation and use of water:

First: domestic water supply, excluding industrial and commercial uses of municipal water supply.

Second: any use of water that involves consumption of less than 10,000 gallons of water a day. In this section "consumption" means water withdrawn from a supply that is lost for immediate further use in the area.

Third: agricultural irrigation, involving consumption in excess of 10,000 gallons a day, and processing of agricultural products.

Fourth: power production, involving consumption in excess of 10,000 gallons a day.

Fifth: other uses, involving consumption in excess of 10,000 gallons a day.

Appropriation and use of surface water from streams during periods of flood flows and high water levels must be encouraged subject to consideration of the purposes for use, quantities to be used, and the number of persons appropriating water.

Appropriation and use of surface water from lakes of less than 500 acres in surface area must be discouraged.

Diversions of water from the state for use in other states or regions of the United States or Canada must be discouraged.

No permit may be issued under this section unless it is consistent with state, regional, and local water and related land resources management plans, if regional and local plans are consistent with statewide plans. The commissioner must not modify or restrict the amount of appropriation from a groundwater source authorized in a permit issued under section 105.44, subdivision 8, between May 1 and October 1 of any year, unless the commissioner determines the authorized amount of appropriation endangers any domestic water supply.

Subd. 1b. **Use less than minimum.** No permit is required for the appropriation and use of less than a minimum amount to be established by the commissioner by rule. Permits for more than the minimum amount but less than an intermediate amount to be specified by the commissioner by rule must be processed and approved at the municipal, county, or regional level based on rules to be established by the commissioner by January 1, 1977. The rules must include provisions for reporting to the commissioner the amounts of water appropriated under local permits.

Subd. 2. **Installations for water use, permits and reports.** It is unlawful for the owner of any installation for appropriating or using surface or underground water to increase the pumping capacity or make any major change in the installation without first applying in writing for, and obtaining, the written permit of the commissioner.

The owner or person in charge of an installation for appropriating or using surface or underground water, whether or not under permit, shall file a statement with the commissioner. The statement shall be filed at the time the commissioner determines necessary for the statewide water information system. The statement must identify the installation's location, its capacity, the purposes for which it is used, and additional information that the commissioner may require. The statement shall be provided on forms provided by the commissioner.

Subd. 3. **Commissioner's examinations.** The commissioner may examine any installation that appropriates or uses surface or underground water. The owner of the installation shall supply information concerning it as the commissioner requires.

Subd. 4. **Measuring and recording quantities used.** It is unlawful for the state, a person, partnership, or association, private or public corporation, county, municipality, or other political subdivision of the state to appropriate or use waters of the state, surface or underground, without measuring and keeping a record of the quantity of water used or appropriated as provided in this section. Each installation for appropriating or using water must be equipped with a device or employ a method to measure the quantity of water appropriated with reasonable accuracy. The commissioner's determination of the method to be used for measuring water quantity must be based on the quantity of water appropriated or used, the source of water, the method of appropriating or using water, and any other facts supplied to the commissioner.

Subd. 5. **Records required.** Records of the amount of water appropriated or used must be kept for each installation. The readings and the total amount of water appropriated must be reported annually to the commissioner of natural resources on or before February 15 of the following year upon forms to be supplied by the commissioner.

The records must be submitted with an annual water appropriation processing fee in the amount established in accordance with the following schedule of fees for each water appropriation permit in force at any time during the year: (1) irrigation permits, $15 for the first permitted 160 acres or part of 160 acres, and $25 for each additional permitted 160 acres or part of 160 acres; (2) for nonirrigation permits, $5 for each ten million gallons or portion of that amount permitted each year. However, the fee must not exceed a total of $500 per permit. The fee is payable regardless of the amount of water appropriated during the year. Failure to pay the fee is sufficient cause for revoking a permit. No fee may be imposed on any state agency, as defined in section 16B.01, or federal governmental agency holding a water appropriation permit.

Subd. 6. **Transfer of permit.** Any appropriation or use permit may be transferred if the permittee conveys the real property where the source of water is located to the next owner of the real property. The new owner shall notify the commissioner of natural resources immediately after an appropriation or use permit is transferred under this section.

History: *1947 c 142 s 5; 1959 c 486 s 1; 1965 c 797 s 1; 1969 c 1129 art 3 s 1; 1973 c 211 s 2; 1973 c 315 s 6; 1974 c 558 s 2,3; 1975 c 105 s 1; 1977 c 446 s 2-4; 1978 c 505 s 2; 1983 c 301 s 108; 1984 c 544 s 89; 1985 c 264 s 2; 1985 c 248 s 70; 1987 c 229 art 2 s 1*

105.415 RULES GOVERNING PERMITS.

Notwithstanding the provision in section 105.41, subdivision 1a, and notwithstanding the provision in section 105.42, subdivision 1a, the commissioner shall, before January 30, 1978, adopt rules containing standards and criteria for the issuance and denial of the permits required by sections 105.41 and 105.42.

History: *1976 c 346 s 18; 1977 c 446 s 5; 1987 c 229 art 2 s 1*

105.416 IRRIGATION FROM GROUNDWATER.

Subdivision 1. **Permit.** Permit applications required by section 105.41, for appropriation of groundwater for agricultural irrigation, must be processed as either class A or class B applications. Class A applications are for wells located in areas for which the commissioner of natural resources has adequate groundwater availability data. Class B are those for other areas. The commissioner shall evaluate available groundwater data, determine its adequacy, and designate areas A and B, statewide. The commissioner shall solicit, receive, and evaluate groundwater data from soil and water conservation districts, and where appropriate revise the area A and B designations. The commissioner of natural resources shall file with the secretary of state a commissioner's

order defining these areas by county and township. Additional areas may be added by a later order of the commissioner. Class A and B applications must be processed in the order received.

Subd. 2. **Class B permits; information requirements.** Class B applications are not complete until the applicant has supplied the following data:

(1) A summary of the anticipated well depth and subsurface geologic formation expected to be penetrated by the well. For glacial drift aquifers, this data must include the logs of test holes drilled to locate the site of the proposed production well.

(2) The formation and aquifer expected to serve as the groundwater source.

(3) The maximum daily, seasonal and annual pumpage expected.

(4) The anticipated groundwater quality in terms of the measures of quality commonly specified for the proposed water use.

(5) The results of a pumping test supervised by the commissioner or a designee of the commissioner, conducted at a rate not to exceed the proposed pumping rate for not more than 72 continuous hours for wells under water table conditions and not more than 24 continuous hours for wells under artesian conditions. Before, during, and after the pumping test the commissioner shall require monitoring of water levels in one observation well located at a distance from the pumping well that the commissioner has reason to believe may be affected by the new appropriation. The permit applicant is responsible for costs of the pumping tests and monitoring in the one observation well. The applicant is responsible for the construction of this one observation well if suitable existing wells cannot be located for this purpose. If the commissioner believes that more than one observation well is needed the commissioner shall instruct the applicant to install and monitor more observation wells. The commissioner shall reimburse the applicant for these added costs.

(6) When the area of influence of the proposed well is determined, the location of existing wells within the area of influence that were reported according to section 156A.07, together with readily available facts on depths, geologic formations, pumping and nonpumping water levels and details of well construction as related to the water well construction code.

The commissioner may in any specific application waive any requirements of clauses (4) to (6) when the necessary data is already available.

Subd. 3. **Issuance of new permits; conditions.** The commissioner shall issue permits for irrigation appropriation from groundwater only where the commissioner determines that:

(1) proposed soil and water conservation measures are adequate based on recommendations of the soil and water conservation districts; and

(2) water supply is available for the proposed use without reducing water levels beyond the reach of vicinity wells constructed in accordance with the water well construction code in Minnesota Rules, parts 4725.1900 to 4725.6500.

History: *1977 c 305 s 45; 1977 c 446 s 18; 1985 c 248 s 69; 1986 c 444; 1987 c 229 art 2 s 1*

105.417 WATER APPROPRIATIONS FROM SURFACE SOURCES.

Subdivision 1. **Waiver.** The commissioner may waive any limitation or requirement in subdivisions 2 to 5 for just cause.

Subd. 2. **Natural and altered natural watercourses.** Where data is available, permits to appropriate water from natural and altered natural watercourses must be limited so that consumptive appropriations are not made from the watercourses during periods of specified low flows. The purpose of the limits is to safeguard water availability for instream uses and for downstream higher priority users located reasonably near the site of appropriation.

Subd. 3. **Waterbasins.** (a) Permits to appropriate water from waterbasins must be limited so that the collective annual withdrawals do not exceed a total volume of

water amounting to one-half acre-foot per acre of waterbasin based on Minnesota department of conservation bulletin No. 25, "An Inventory of Minnesota Lakes."

(b) As a condition to a surface water appropriation permit, the commissioner of natural resources shall set an elevation for the subject waterbasin, below which no appropriation is allowed. During the determination of the elevation called the "protection elevation," the commissioner shall take into account the elevation of important aquatic vegetation characteristics related to fish and wildlife habitat, existing uses of the waterbasin by the public and riparian land owners, the total volume within the waterbasin and the slope of the littoral zone.

(c) As part of an application for appropriation of water from a waterbasin less than 500 acres in surface area, the applicant shall get a statement containing as many signatures as the applicant can obtain of landowners with land riparian to the subject waterbasin. It must state their support to the proposed appropriation, and it must show the number of landowners whose signatures the applicant could not obtain.

Subd. 4. **Trout streams.** Permits issued after June 3, 1977, to appropriate water from streams designated trout streams by the commissioner's orders under section 97C.021, must be limited to temporary appropriations.

Subd. 5. **Contingency planning.** No application for use of surface waters of the state is complete until the applicant submits, as part of the application, a contingency plan that describes the alternatives the applicant will use if further appropriation is restricted due to the flow of the stream or the level of a waterbasin. No surface water appropriation shall be allowed unless the contingency plan is feasible or the permittee agrees to withstand the results of no appropriation.

History: *1977 c 446 s 19; 1986 c 386 art 4 s 21; 1986 c 444; 1987 c 229 art 2 s 1*

105.418 CONSERVATION OF PUBLIC WATER SUPPLIES.

During periods of critical water deficiency as determined by the governor and declared by order of the governor, public water supply authorities appropriating water shall adopt and enforce restrictions consistent with rules adopted by the commissioner of natural resources within their areas of jurisdiction. The restrictions must limit lawn sprinkling, car washing, golf course and park irrigation, and other nonessential uses and have appropriate penalties for failure to comply with the restrictions. The commissioner may adopt emergency rules according to sections 14.29 to 14.36 relating to matters covered by this section during the year 1977. Disregard of critical water deficiency orders, even though total appropriation remains less than that permitted, is grounds for immediate modification of any public water supply authority's appropriator's permit.

History: *1977 c 446 s 20; 1987 c 229 art 2 s 1*

105.42 PERMITS; WORK IN PUBLIC WATERS.

Subdivision 1. **Construction.** It is unlawful for the state, a person, partnership, association, private or public corporation, county, municipality or other political subdivision of the state, to construct, reconstruct, remove, abandon, transfer ownership of, or make any change in any reservoir, dam or waterway obstruction on any public water; or in any manner, to change or diminish the course, current, or cross-section of any public waters, wholly or partly within the state, by any means, including but not limited to, filling, excavating, or placing of materials in or on the beds of public waters, without first getting a written permit from the commissioner. Application for a permit must be in writing to the commissioner on forms prescribed by the commissioner. **No permit shall be required for work in altered natural watercourses that are part of drainage systems established under sections 106A.005 to 106A.811 and chapter 112 when the work in the waters is undertaken under those chapters.**

This section does not apply to any public drainage system established under sections 106A.005 to 106A.811 that does not substantially affect public waters.

The commissioner, subject to the approval of the county board, may grant, and